



PHASE 2 GROUND WATER STUDY

TRONOX NAUM AMBROSIA LAKE AREA –
SAN MATEO CREEK BASIN LEGACY URANIUM SITE

TRONOX Quarterly Meeting
October 25, 2017
Albuquerque, NM

MULTI-PHASED GROUND WATER INVESTIGATION

Phase 1

*Alluvial Aquifer
San Mateo Creek Basin
2012 – 2016*



Phase 2

*Bedrock & Alluvial Aquifers
San Mateo Creek Basin*

*Refine Conceptual Site Model
2015 – 2018*



PHASE 2 STUDY OBJECTIVES

- ASSESS GROUND WATER IMPACTS FROM TRONOX MINES AND OTHER WET MINES
 - Former Kerr-McGee Mines
 - Primarily located in NAUM Ambrosia Lake Impact Area
 - Within San Mateo Creek Basin
- EXPAND ON 2015 PHASE 1 INVESTIGATION OF ALLUVIUM
- ASSESS BEDROCK AQUIFERS
- REFINE CONCEPTUAL SITE MODEL

Legacy of Uranium Mining in Northwestern New Mexico



- Uranium Mine
- ▲ Mill Location
- City or Town
- ▭ Uranium Sub-District
- ▭ Pueblo of Acoma
- ▭ Pueblo of Laguna
- ▭ Navajo Nation Chapter
- ▭ Navajo Nation Ownership
- ▭ San Mateo Basin
- ▭ NPL Site
- ▭ County
- Land Ownership for Tracts with Mines
 - ▭ Bureau of Land Management
 - ▭ Forest Service
 - ▭ Tribal Land
 - ▭ Private Land
 - ▭ State Land

Note:
The Land Ownership layer as displayed is not complete. The only areas displayed are those containing one or more mines.

Sources:
MMD Legacy Uranium Mine Inventory: 12/2008.
EPA Region 6 National Priorities List (NPL), 5/2015.
Bureau of Land Management (BLM) Land Ownership.
Navajo Land Department 2016, Census Bureau 2000
TIGER/Line, ESRI World Shaded Relief.

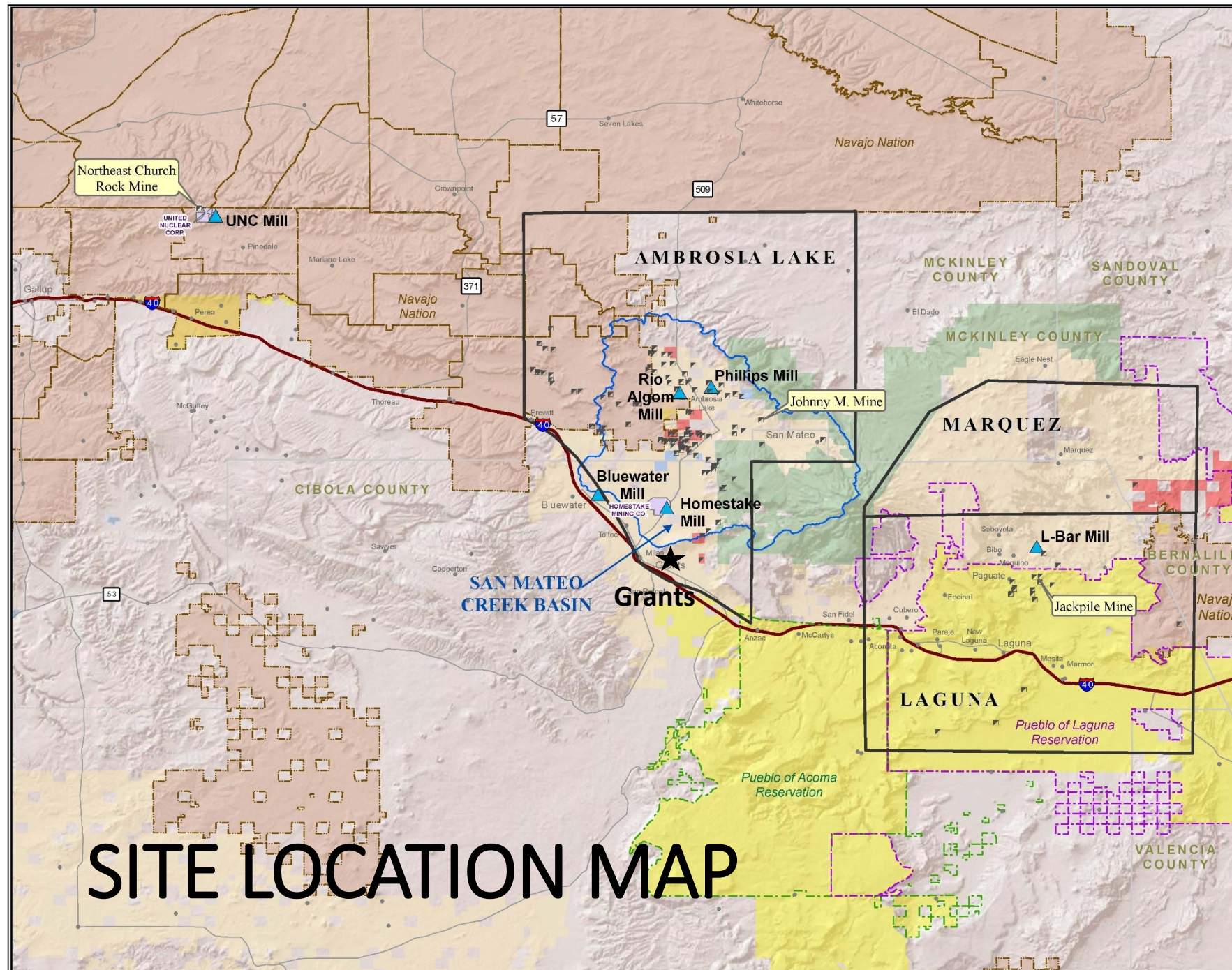


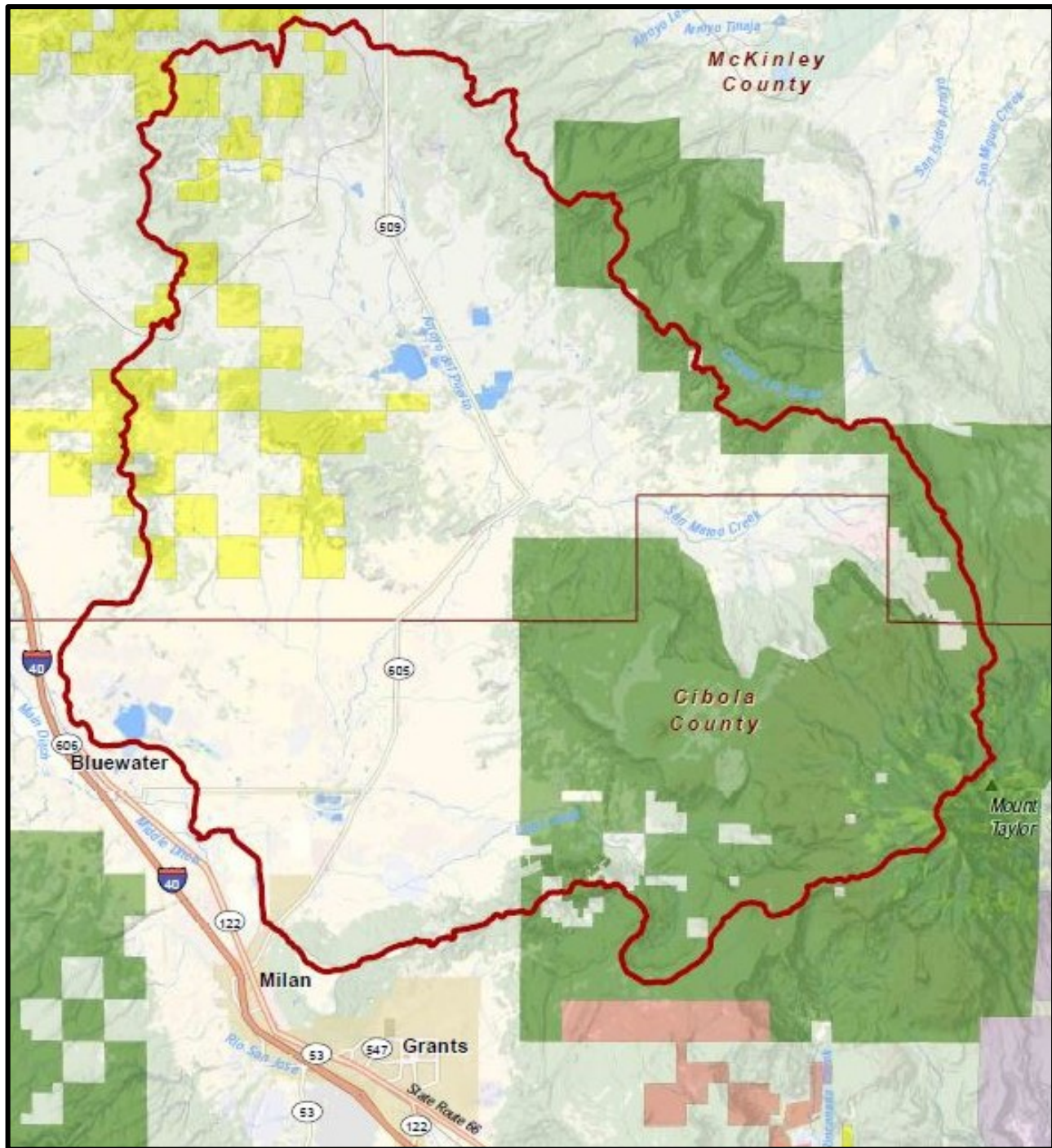
EPA Region 6
Superfund
GIS Support
04/25/2016



20160425ML01





SITE LOCATION MAP





SITE MAP

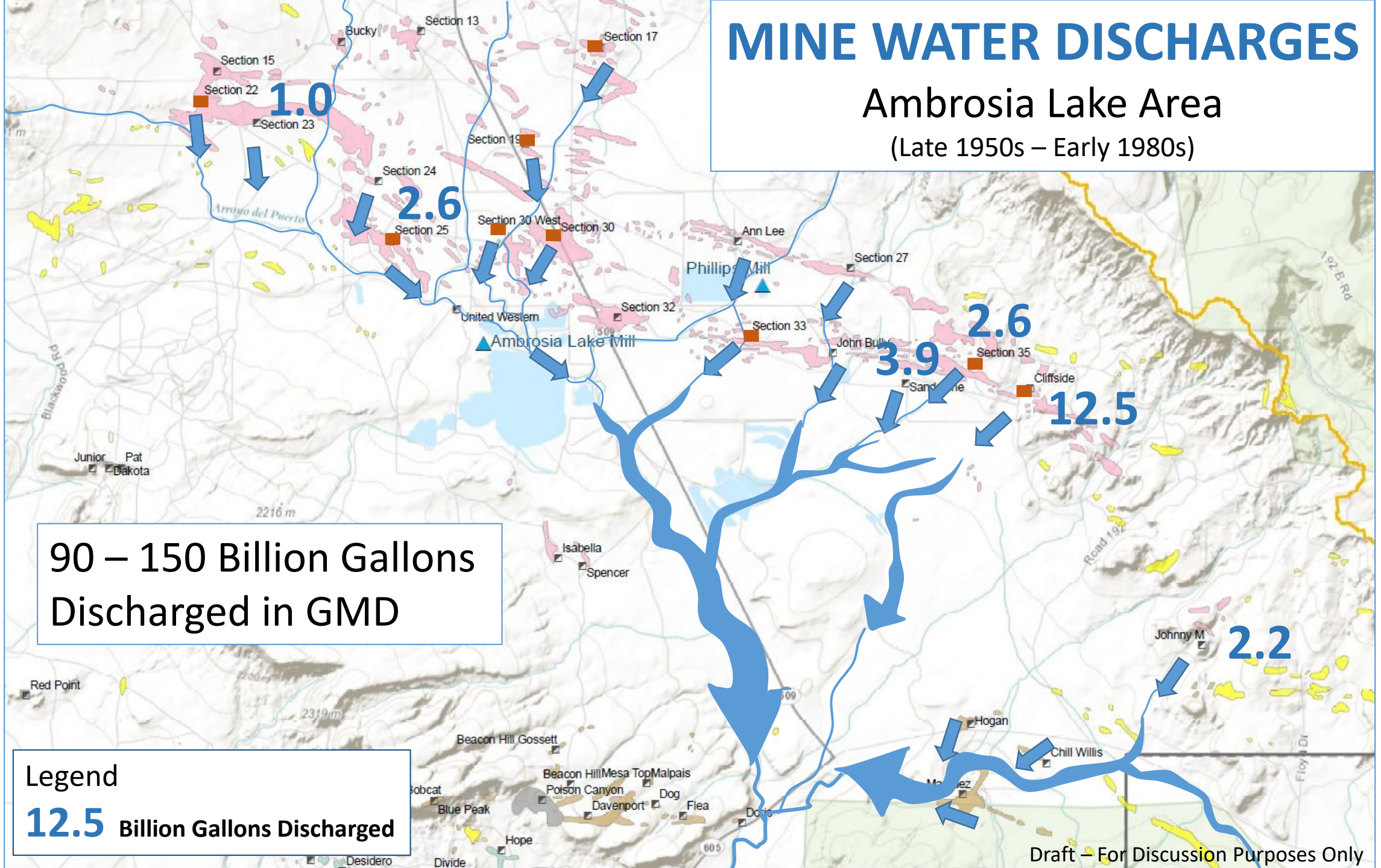
LEGEND

-  Navajo Land
-  Forest Service Land
-  Acoma Pueblo Land
-  Laguna Pueblo Land

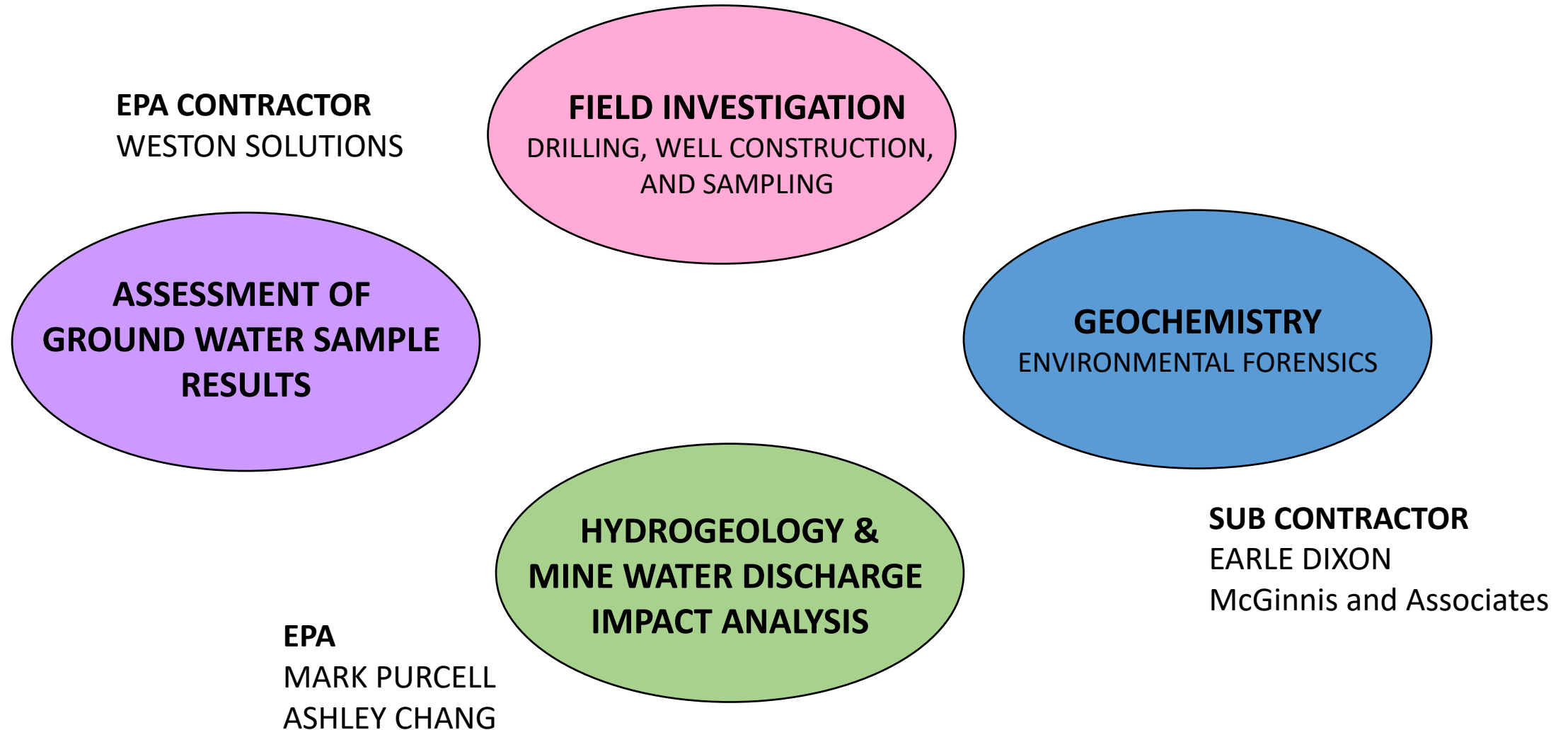
MINE WATER DISCHARGES

Ambrosia Lake Area

(Late 1950s – Early 1980s)



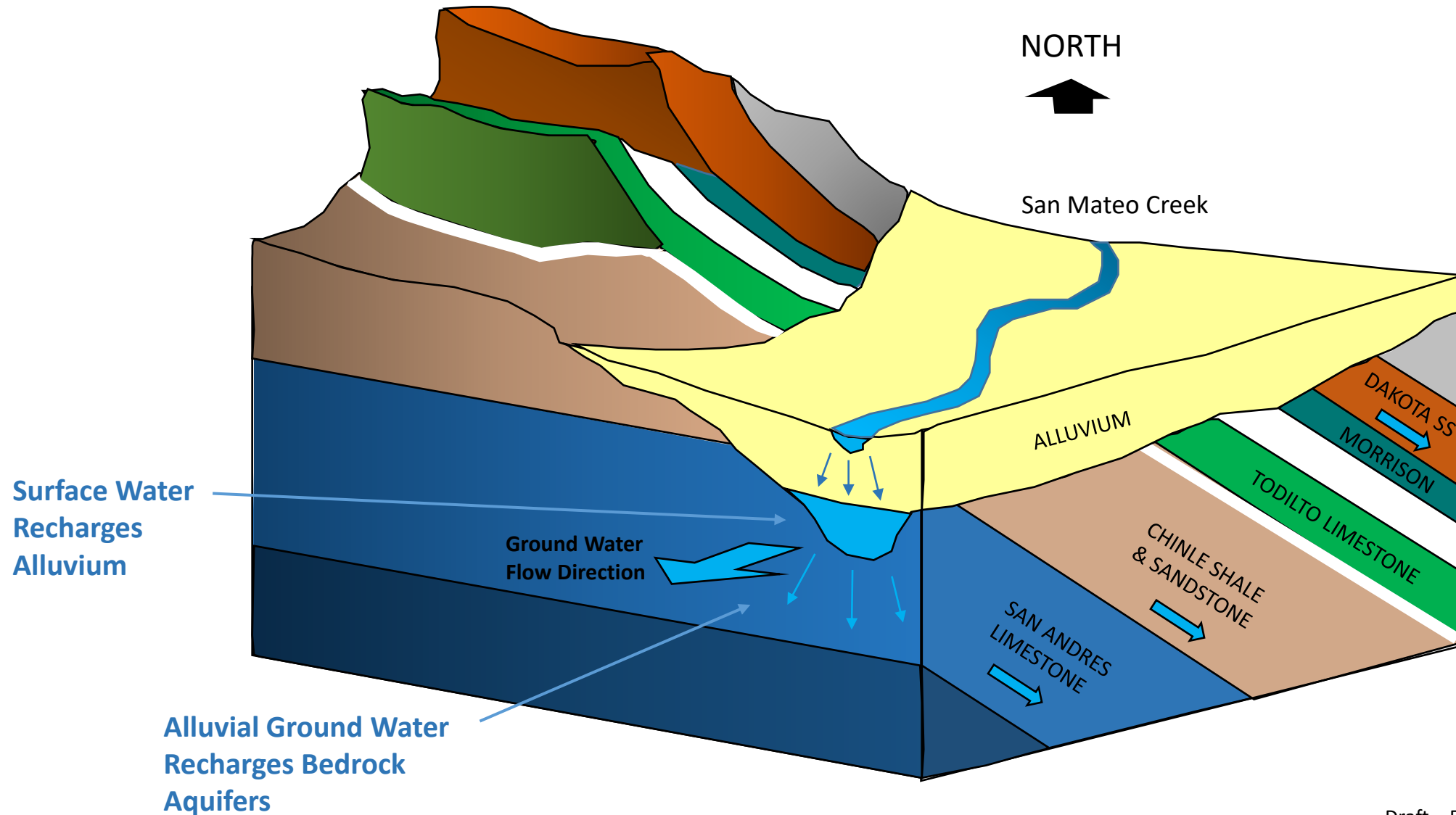
MAJOR PHASE 2 COMPONENTS



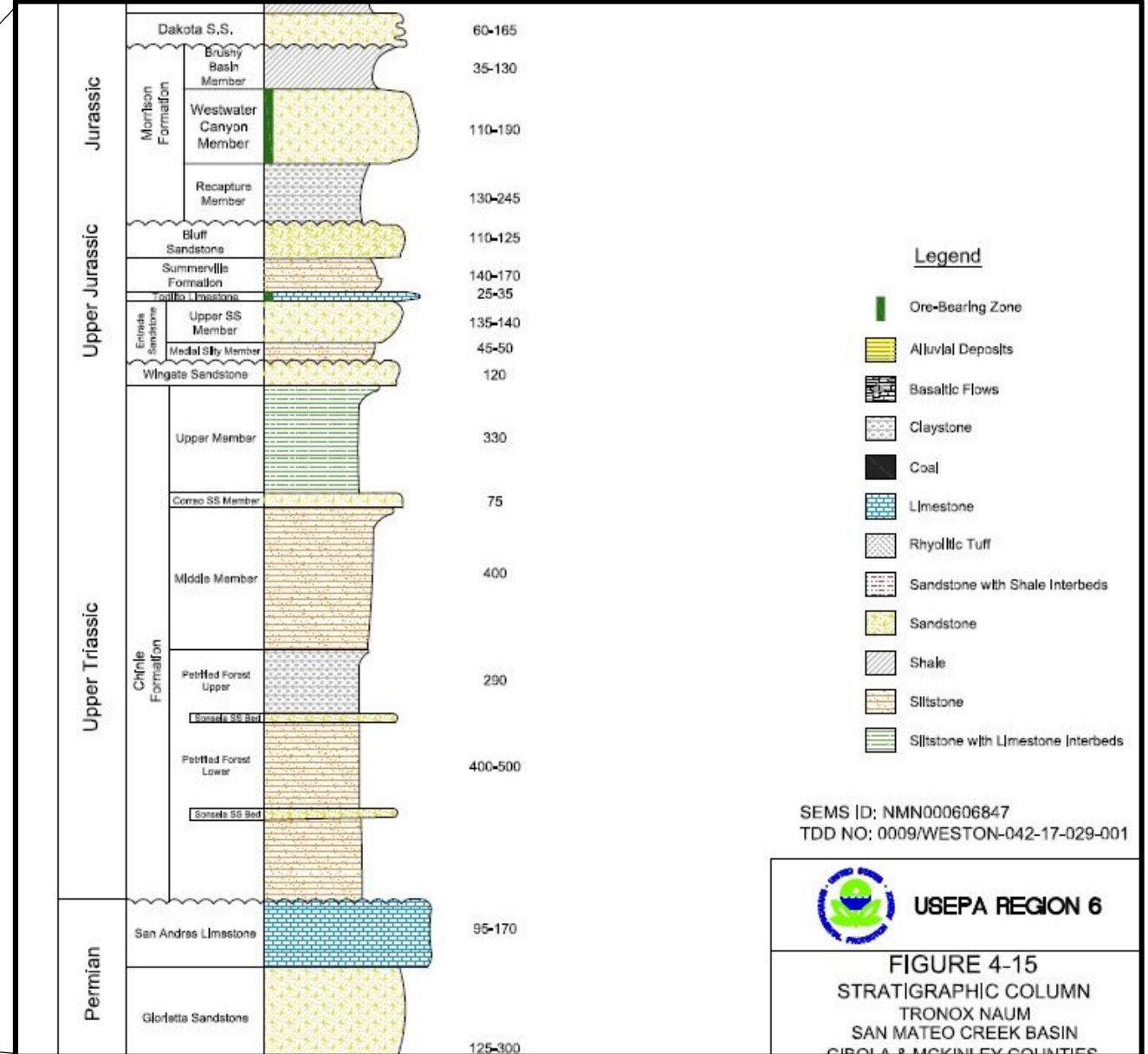
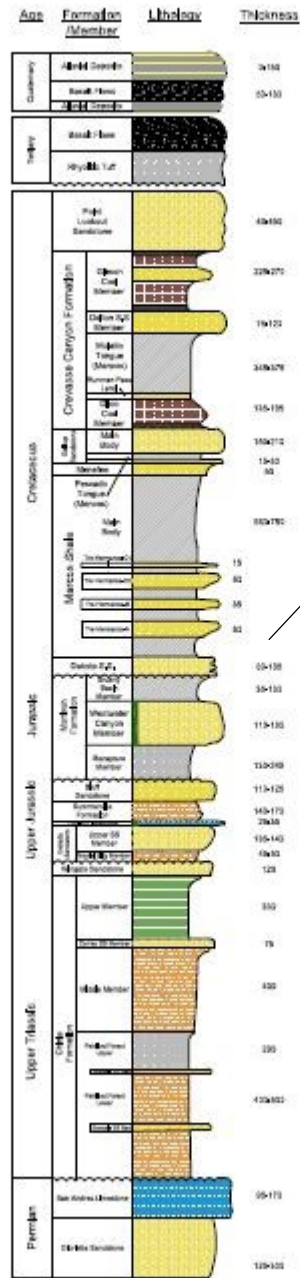
PHASE 2 REPORT DRAFT OUTLINE

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RESULTS
GEOCHEMISTRY
LEGACY MINE DISCHARGE WATER IMPACT ANALYSIS ★
DISCUSSION
CONCLUSIONS

CONCEPTUAL SITE GROUND WATER MODEL



STRATIGRAPHIC COLUMN



Legend

- Ore-Bearing Zone
- Alluvial Deposits
- Basaltic Flows
- Claystone
- Coal
- Limestone
- Rhyolitic Tuff
- Sandstone with Shale Interbeds
- Sandstone
- Shale
- Siltstone
- Siltstone with Limestone Interbeds

SEMS ID: NMN000606847
TDD NO: 0009/WESTON-042-17-029-001



USEPA REGION 6

FIGURE 4-15
STRATIGRAPHIC COLUMN
TRONOX NAUM
SAN MATEO CREEK BASIN
GIBOLA & MCKINLEY COUNTIES

SUMMARY OF IMPACTS FROM FORMER MILLS




- REGULATED BY U.S. NUCLEAR REGULATORY COMMISSION
 - Reclamation
 - Decommissioning and Closure
 - Ground Water Restoration
- DOE LEGACY MANAGEMENT PROGRAM
 - Long-Term Custody and Care
- URANIUM MILL TAILING RADIATION CONTROL ACT (UMTRCA) OF 1978
- FOUR MILLING AND TAILING DISPOSAL FACILITIES
 - RIO ALGOM AMBROSIA LAKE FACILITY
 - DOE AMBROSIA LAKE DISPOSAL FACILITY (FORMER PHILLIPS MILL) – Title I Site
 - DOE BLUEWATER DISPOSAL SITE
 - HOMESTAKE MINING COMPANY NPL SITE



ALTERNATE CONCENTRATION LIMITS (ACLs)

- UNDER UMTRCA, NRC HAS AUTHORITY TO CONTROLS HAZARDS AT TITLE II SITES
 - Implementation of Standards for Protection of Human Health/Environment
 - Ground Water Protection Standards Established by EPA at 40 CFR Part 192
- CONCENTRATION LIMITS (STANDARDS) ESTABLISHED IN SITE LICENSE
- NRC MAY ESTABLISH AN ACL THAT IS LESS RESTRICTIVE THAN STANDARD
 - When GWPS or Background are not practically achievable
 - ACL Must Be As Low As Reasonably Achievable (ALARA)
 - ACL Must Be Protective of Human Health and Environment

LEGEND

-  Alluvium
Impacted by
Mill and Mine
Discharge Water
-  Impacted
Tre Hermanos B
Well
-  Impacted Dakota
Well

The map displays the DOE Ambrosia Lake Disposal Site (Formerly Phillips Mill) in New Mexico. A large blue area represents the lake, with various monitoring points labeled around its perimeter, including Section 26 through Section 35, and specific codes like 30-02 KD, 30-01 TRA, 30-48 KD R, 31-02 TRB R, 31-67 T, 32-45 KD R, 33-01 TRA, 34-02 KD, 36-01 TRB, 36-02 TRB, and 36-06 KD. A red circle highlights a point near 36-06 KD. A yellow shaded area at the bottom left indicates the Rio Algom LLC Ambrosia Lake Facility NRC License SUA-1473. A purple outline marks the U.S. Nuclear Regulatory Commission Source Materials License Boundary. A road labeled 509 runs along the bottom right. An inset map in the top right corner shows the location within New Mexico.

Ground water restoration ceased in 2005

ACLs Established by NRC in 2006

No Ground Water Restoration
DOE Determined that ground water in uppermost aquifers of limited use based on aquifer yield.

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Modified from Rio Algom

Draft – For Discussion Purposes Only
Modified from Rio Algom

Draft – For Discussion Purposes Only



LEGEND

- Alluvium Monitoring Well
- Upper Chinle Monitoring Well
- Middle Chinle Monitoring Well
- San Andres/Glorietta (SAG) Monitoring Well
- Former Mill Location
- Homestake Impoundment
- NRC License Boundary (Approximate)
- San Mateo Creek Basin
- Fault (location interpreted with higher level of uncertainty because of lack of geological data)
- Fault (location adapted from that shown in Homestake Mining Company 2016 Annual Report)
- Fault Indicator, Bar and ball on downthrown side
- Groundwater Flow Direction by Formation
- Tailing Seepage Impact (dashed where inferred)
- Alluvium
- Upper Chinle SS
- Middle Chinle SS
- Lower Chinle SS
- San Andres/Glorietta

DEMS ID: NMN000505947
TSD NO: 0006WESTON-545-17-029-001

SOURCES:

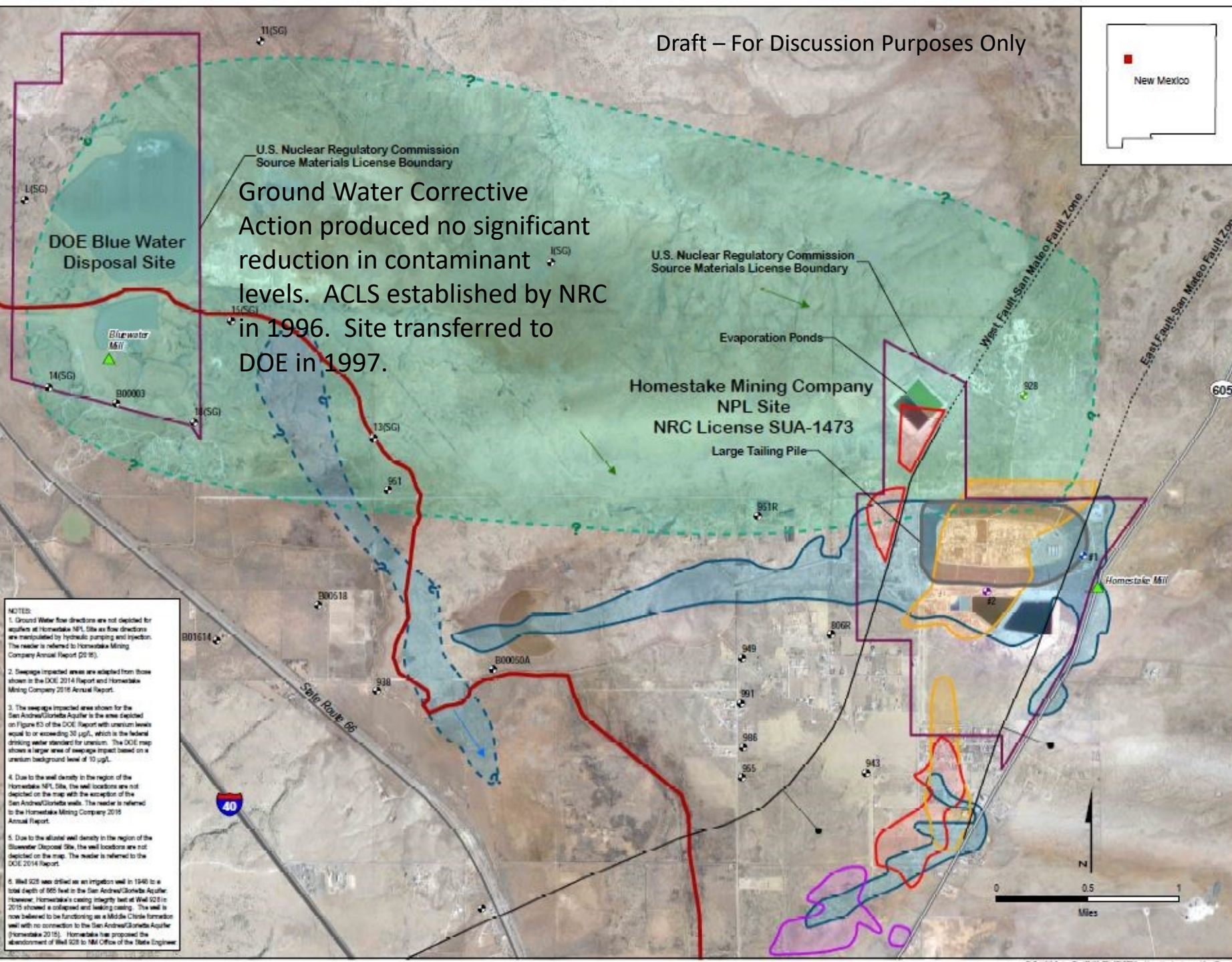
- Google, 2017
- Tailing Seepage Impacts modified from DOE 2014, HMC 2016 Report



USEPA REGION 6

FIGURE 4-19
TAILING SEEPAGE IMPACTS - MILAN AREA
TRONOX NAUM
SAN MATEO CREEK BASIN
CIBOLA & MCKINLEY COUNTIES,
NEW MEXICO

DATE	PROJECT NO	SCALE
JULY 2017	20468.0 12 000 5400.01	AS SHOWN



NOTES:

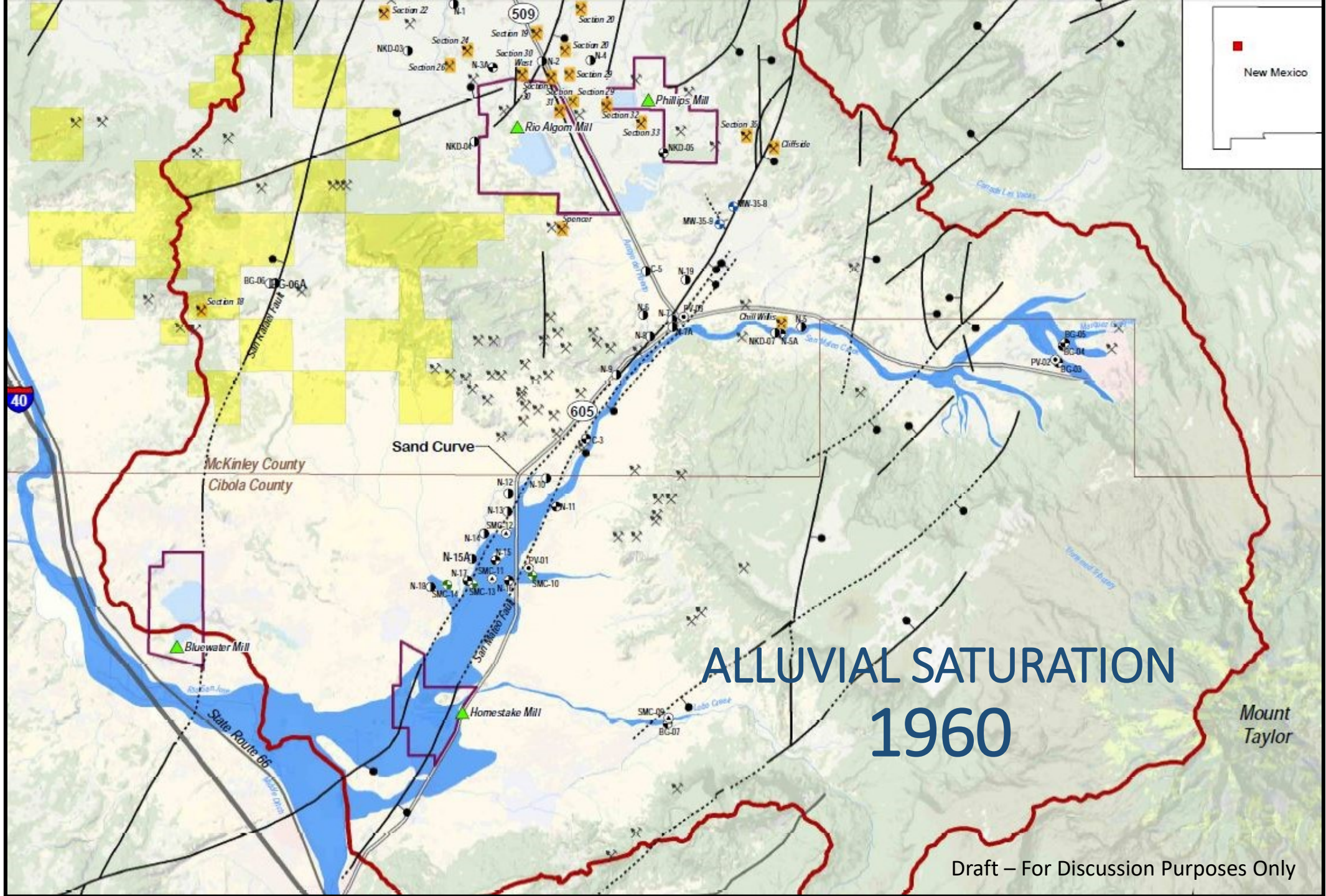
- Groundwater flow directions are not depicted for aquifers at Homestake NPL Site as flow directions are manipulated by hydraulic pumping and injection. The reader is referred to Homestake Mining Company Annual Report (2016).
- Seepage impacted areas are adapted from those shown in the DOE 2014 Report and Homestake Mining Company 2016 Annual Report.
- The seepage impacted area shown for the San Andres/Glorietta Aquifer is the area depicted on Figure 63 of the DOE Report with uranium levels equal to or exceeding 30 µg/L, which is the federal drinking water standard for uranium. The DOE map shows a larger area of seepage impact based on a uranium background level of 10 µg/L.
- Due to the well density in the region of the Homestake NPL Site, the well locations are not depicted on the map with the exception of the San Andres/Glorietta wells. The reader is referred to the Homestake Mining Company 2016 Annual Report.
- Due to the alluvial well density in the region of the Bluewater Disposal Site, the well locations are not depicted on the map. The reader is referred to the DOE 2014 Report.
- Well 928 was drilled as an irrigation well in 1940 to a total depth of 665 feet in the San Andres/Glorietta Aquifer. However, Homestake's casing integrity test at Well 928 in 2015 showed a collapsed and leaking casing. The well is now believed to be functioning as a Middle Chinle formation well with no connection to the San Andres/Glorietta Aquifer (Homestake 2015). Homestake has proposed the abandonment of Well 928 to NM Office of the State Engineer.

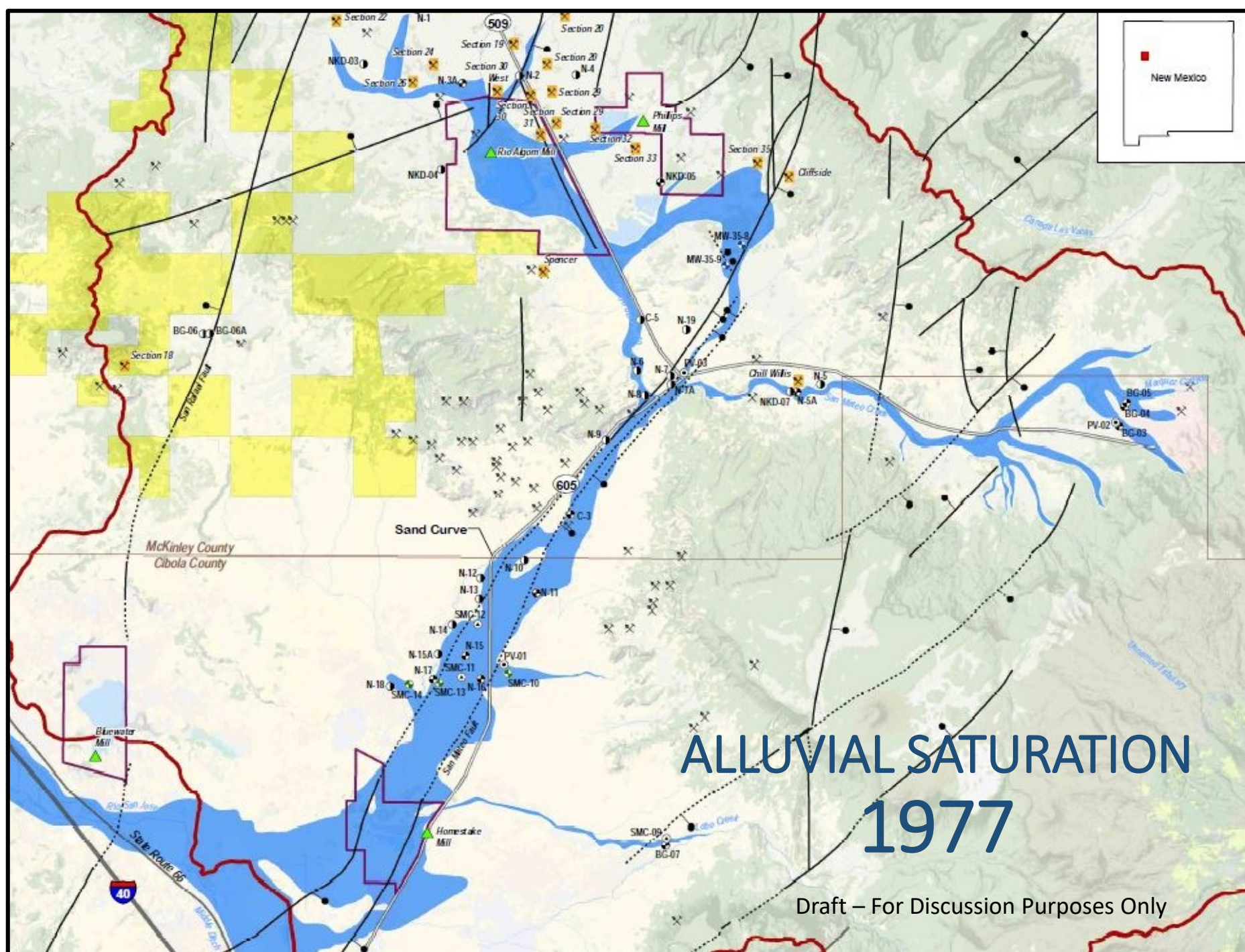
MAJOR HYDROSTRATIGRAPHIC UNITS

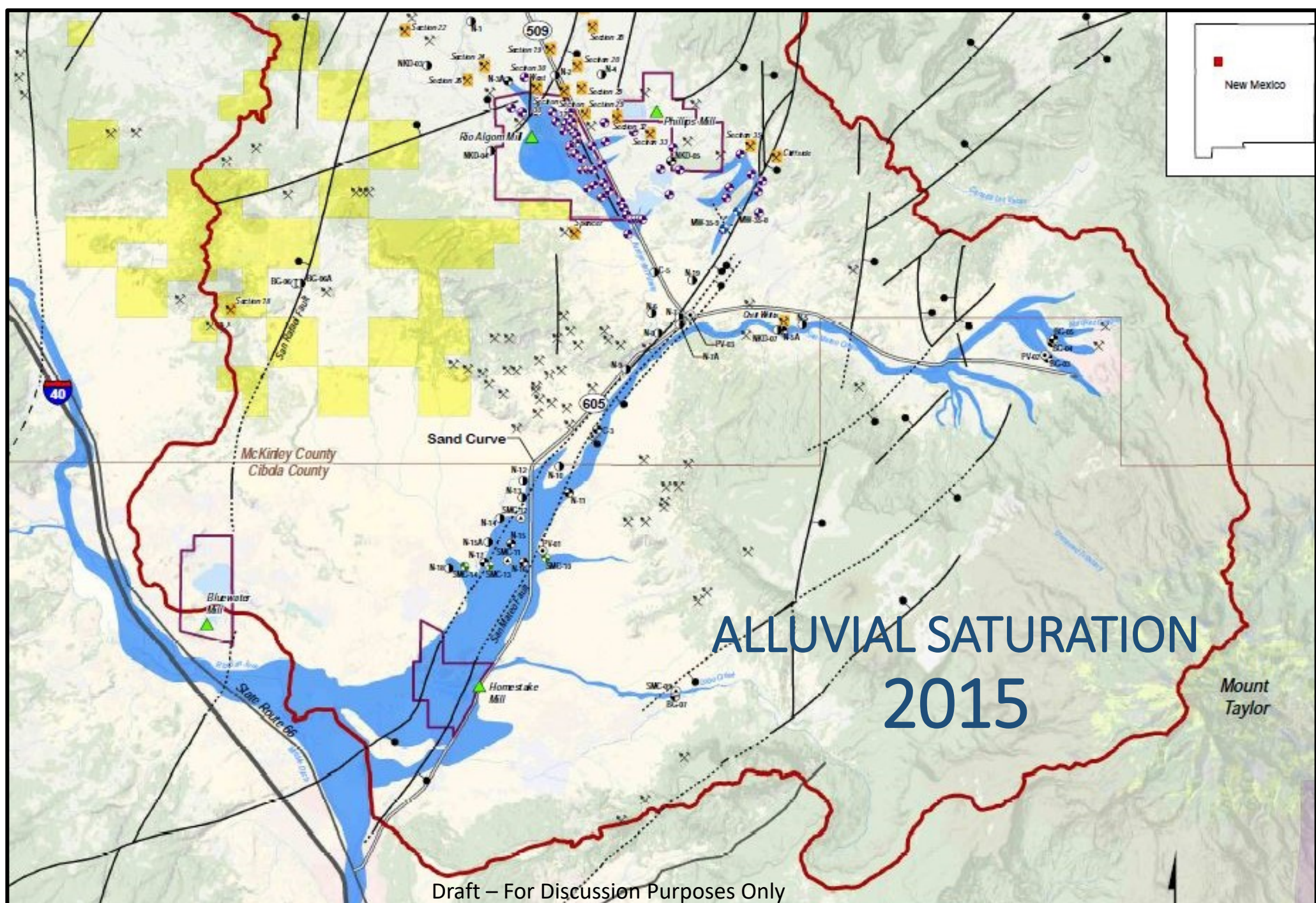
- ALLUVIUM
- ALLUVIUM – BEDROCK MIX
- BEDROCK
 - Dakota Sandstone
 - Morrison Formation (Westwater Canyon Member – Ore Bearing Zone)
 - Chinle Formation
 - San Andres Limestone – Glorieta Sandstone (SAG) Formations

ALLUVIUM

- BASIN-WIDE SATURATION
- BASIN-WIDE GROUND WATER FLOW DIRECTION
- AMBROSIA LAKE AREA FLOW DIRECTION
- WATER QUALITY

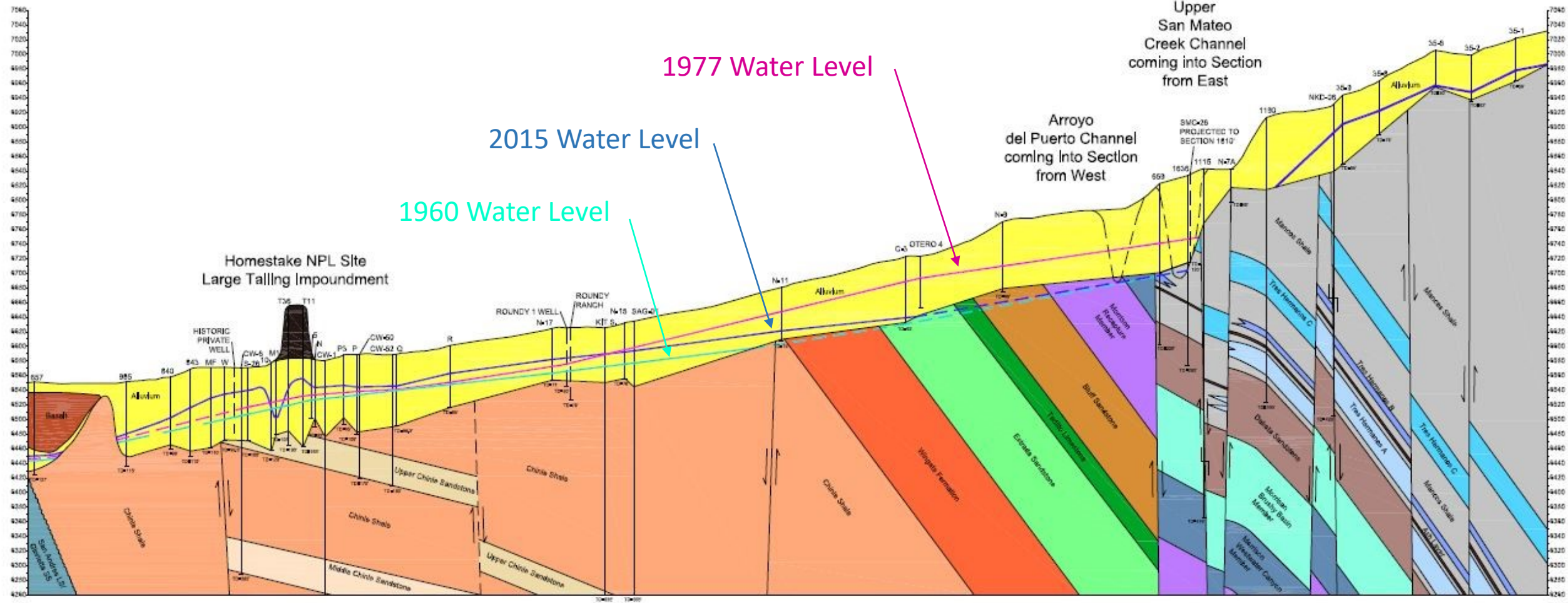






D'

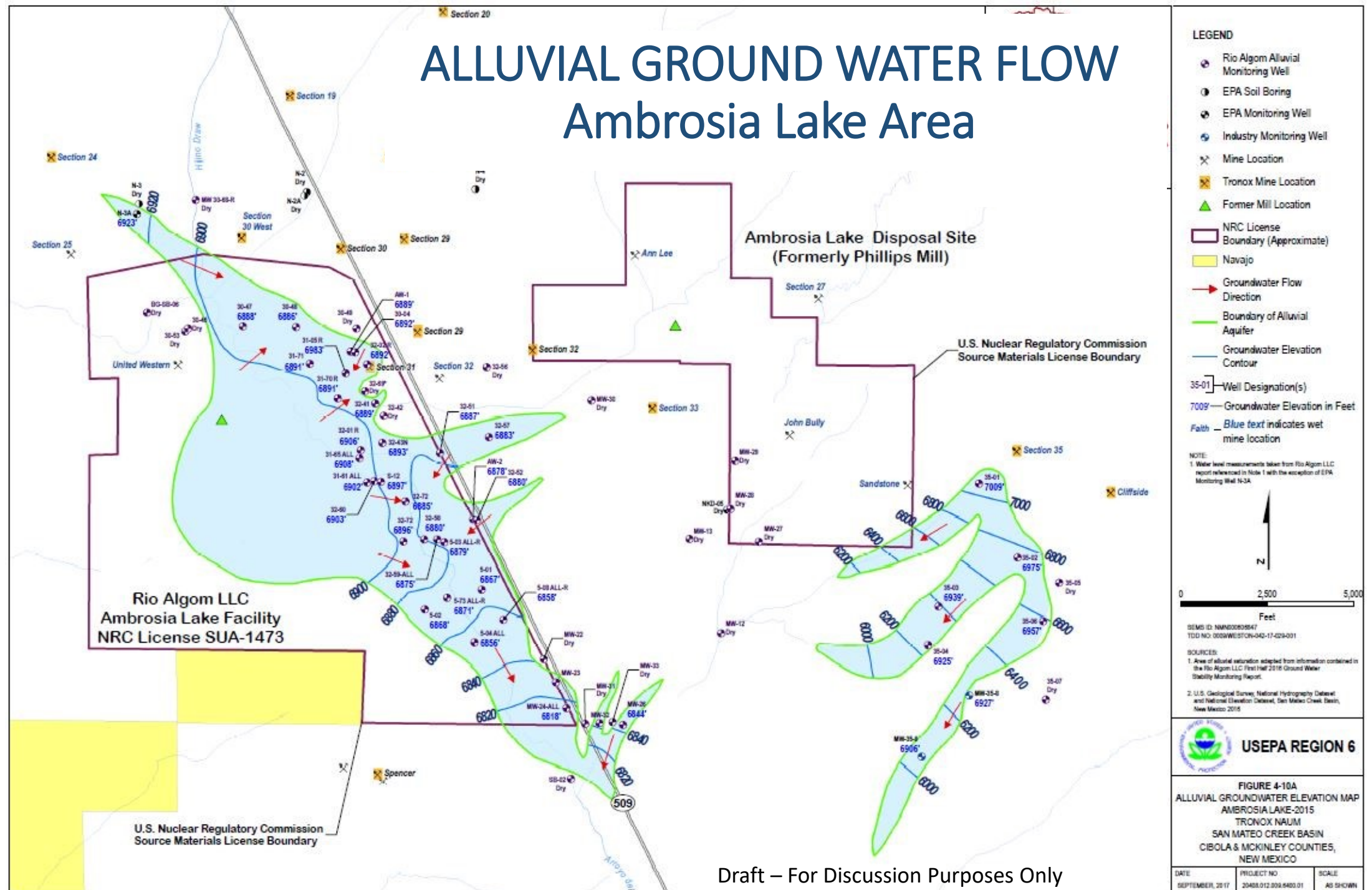
NO



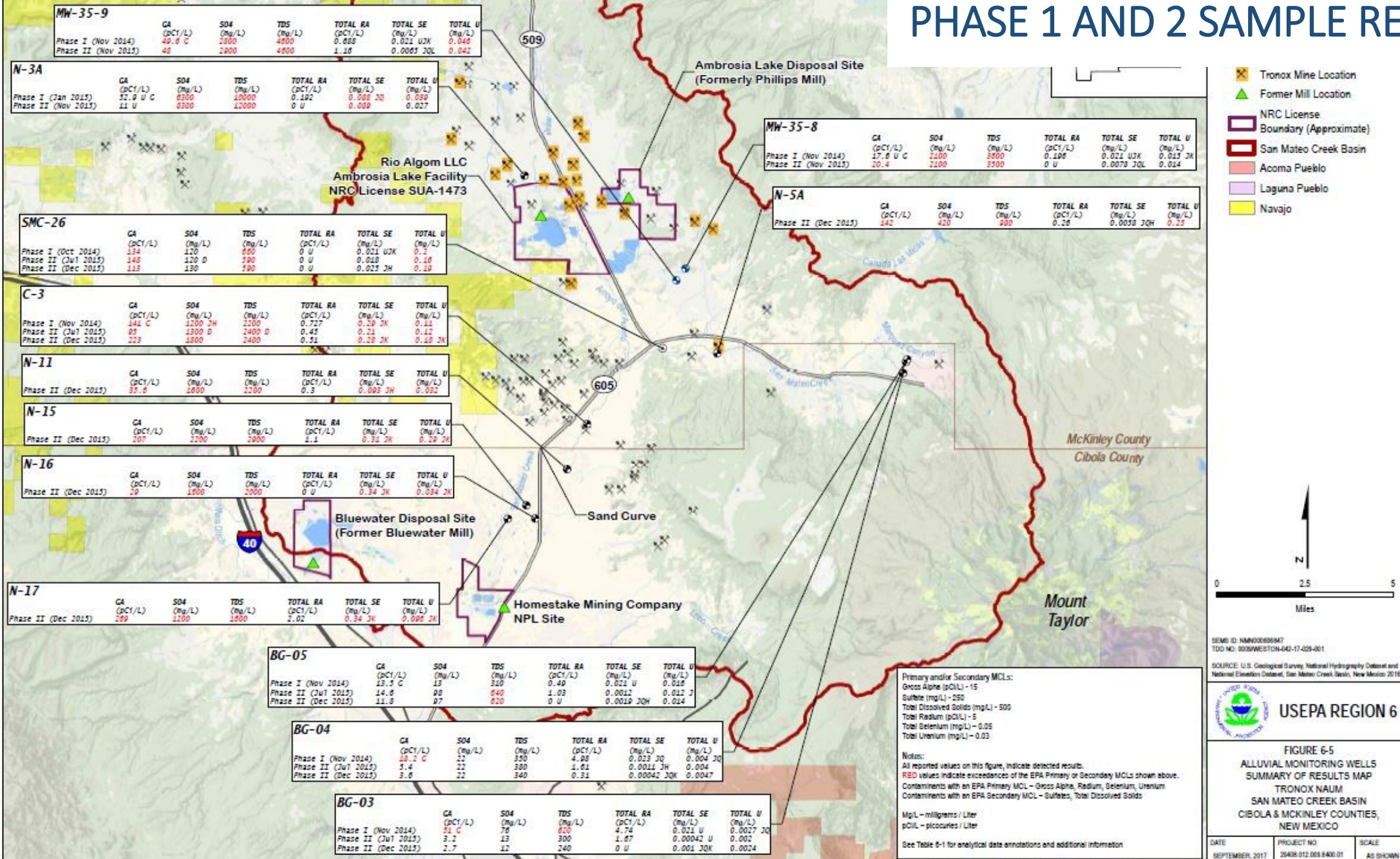
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ALLUVIAL GROUND WATER FLOW Ambrosia Lake Area

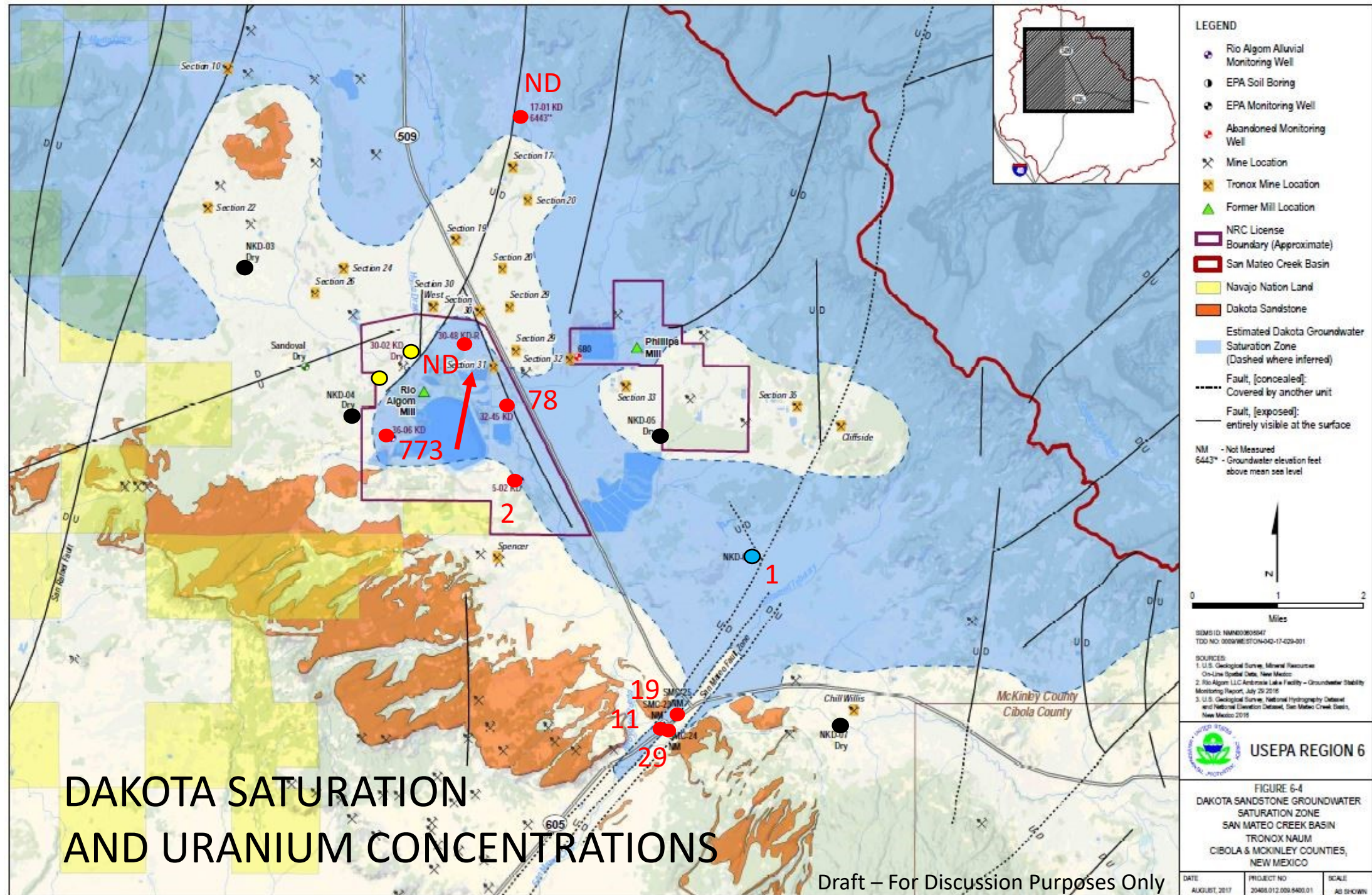


ALLUVIAL WATER QUALITY PHASE 1 AND 2 SAMPLE RESULTS



DAKOTA SANDSTONE AQUIFER

- SATURATION
- GROUND WATER FLOW DIRECTION
- WATER QUALITY
- DETAILED CROSS-ROADS AREA



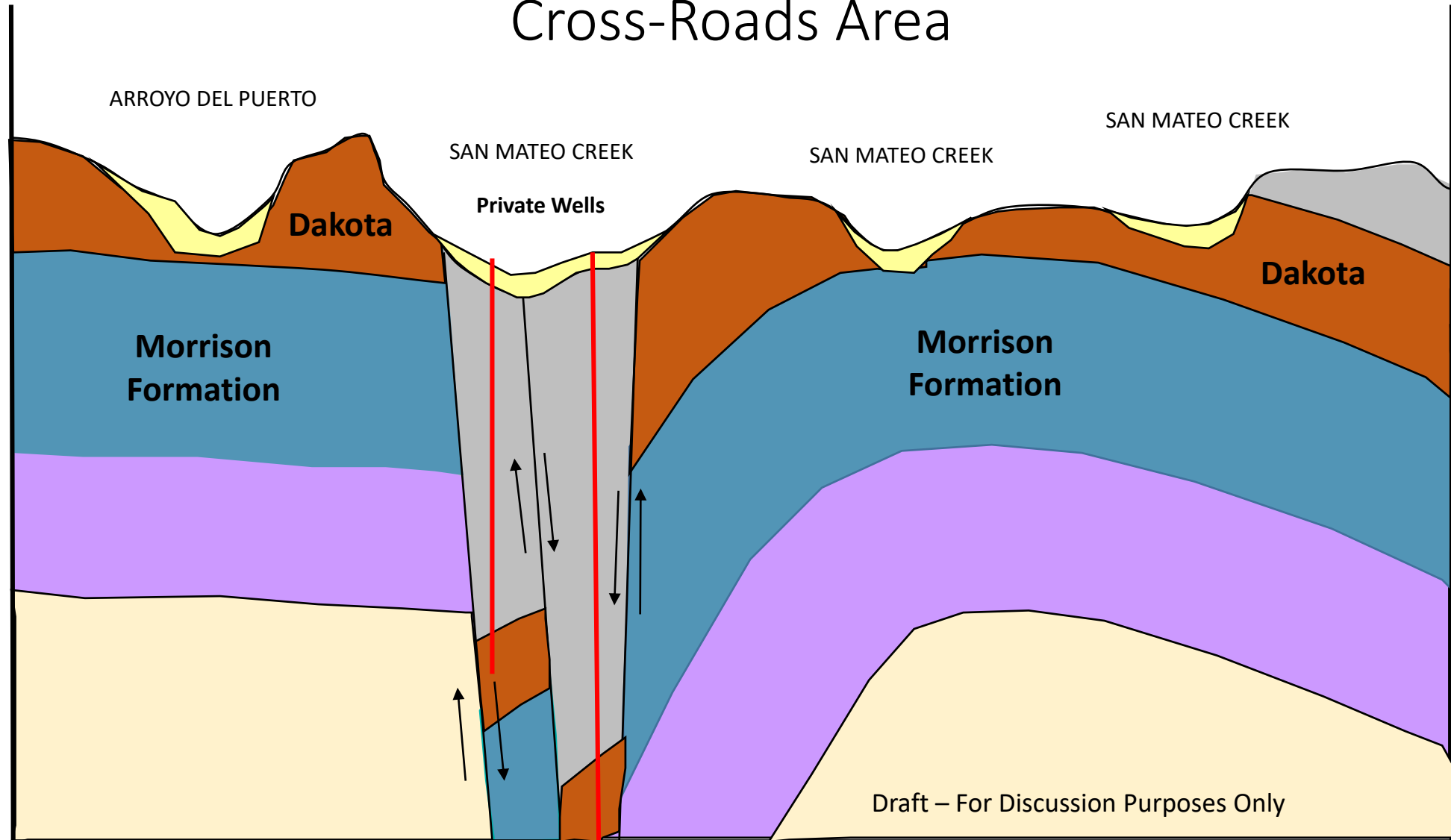
GEOLOGIC CROSS SECTION A-A'

A

San Mateo Fault Zone

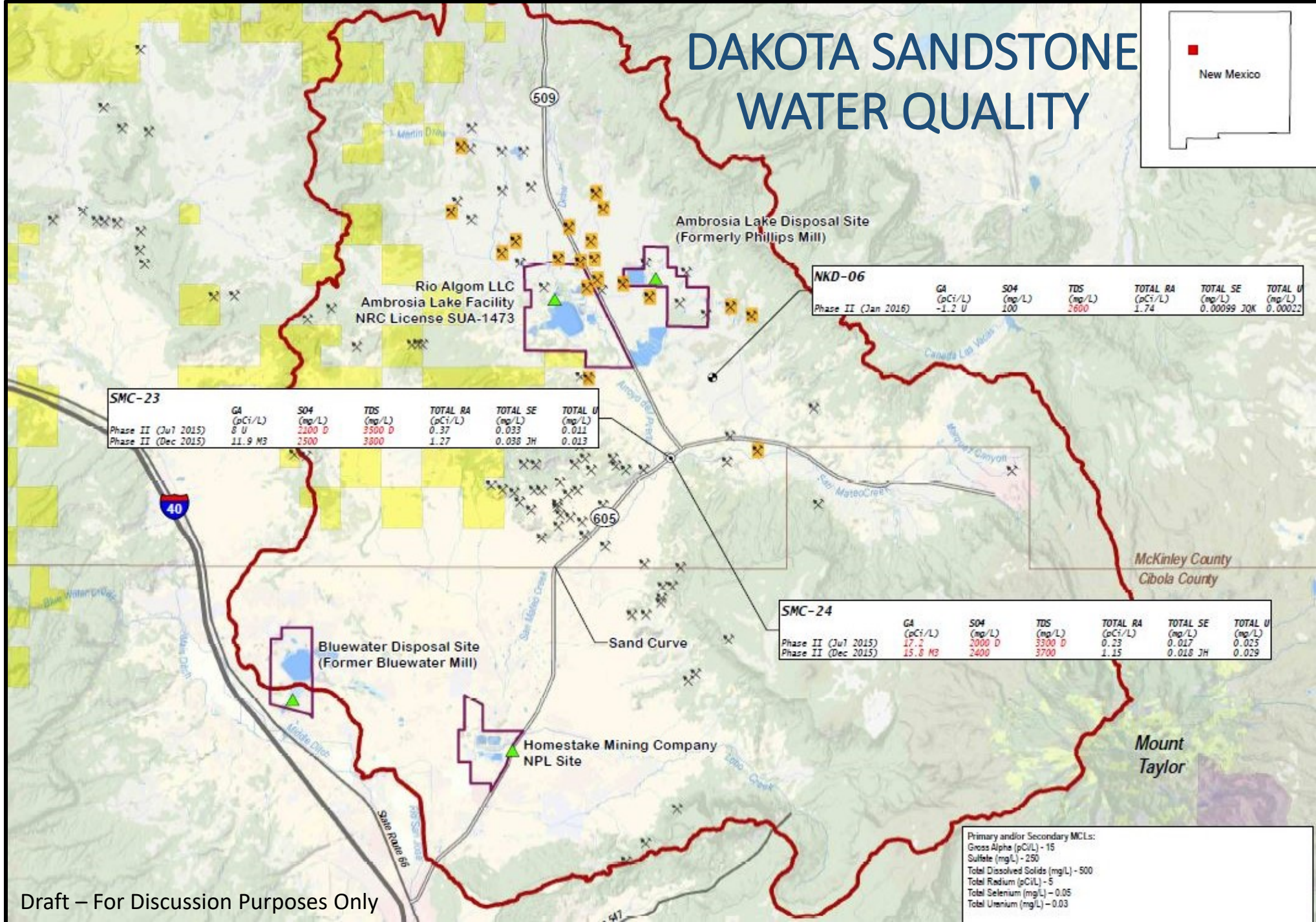
Cross-Roads Area

A'



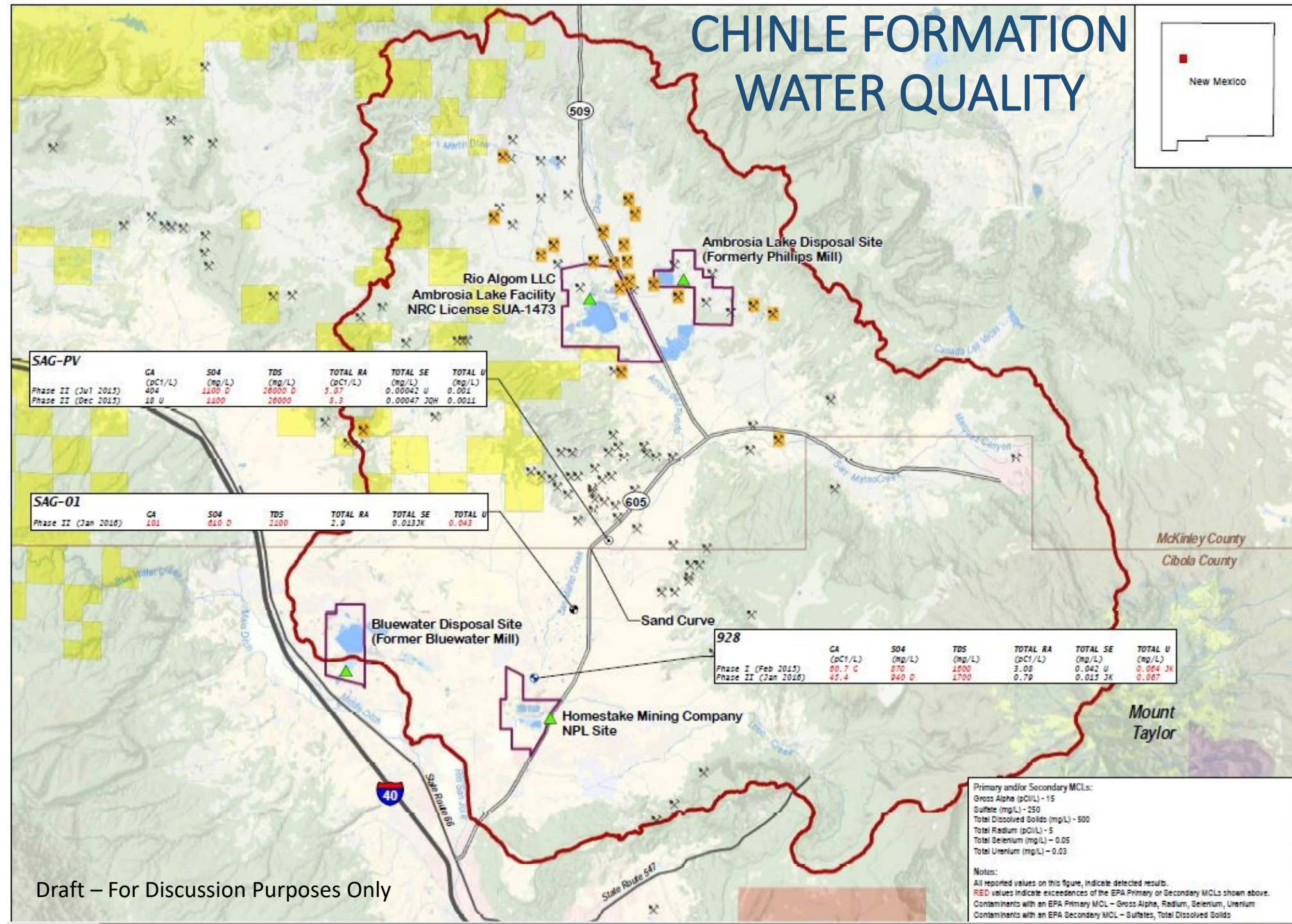
DAKOTA SANDSTONE WATER QUALITY

New Mexico



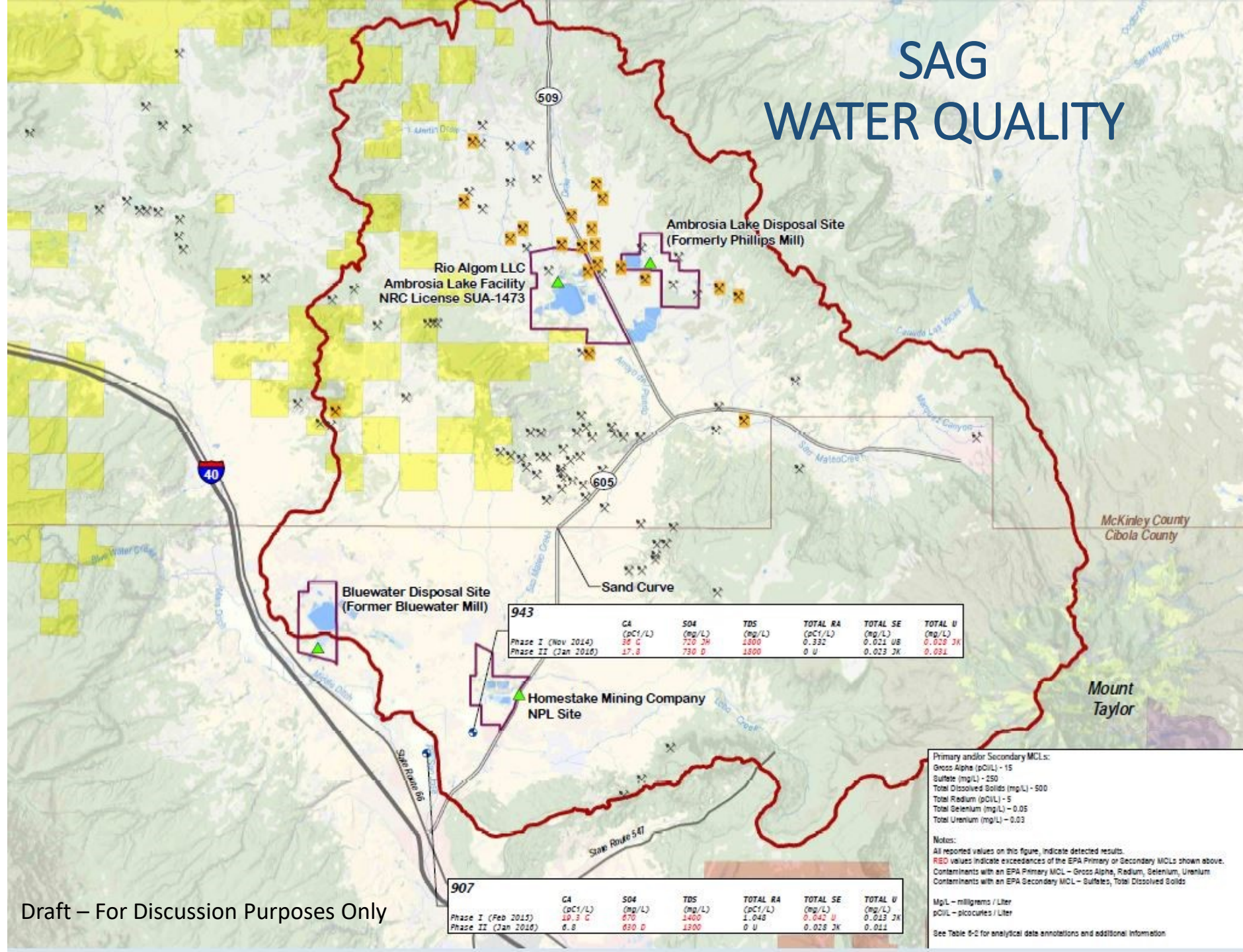
Draft – For Discussion Purposes Only

CHINLE FORMATION WATER QUALITY



Draft – For Discussion Purposes Only

SAG WATER QUALITY



Draft – For Discussion Purposes Only

GEOCHEMISTRY – ENVIRONMENTAL FORENSICS

- SYSTEMATIC INVESTIGATION OF WATER TYPES
 - Major Ions (Cations and Anions)
 - Trilinear Diagrams
 - Classify Water Ion Composition
 - Stiff Diagrams
 - Presents Ion Concentration Data as Graphic Shapes
 - Ion to Ion Relationships
 - Uranium Activity Ratios
 - Stable Isotopes – Oxygen, Hydrogen, Sulfur, Carbon
 - Use as Tracer or Fingerprint to Source
- MULTIPLE LINES OF EVIDENCE

Mine Discharge Water is primarily from Morrison Fm (Ore Zone) and Overlying Dakota Sandstone Formation (Drained into Morrison Fm)



GEOCHEMISTRY

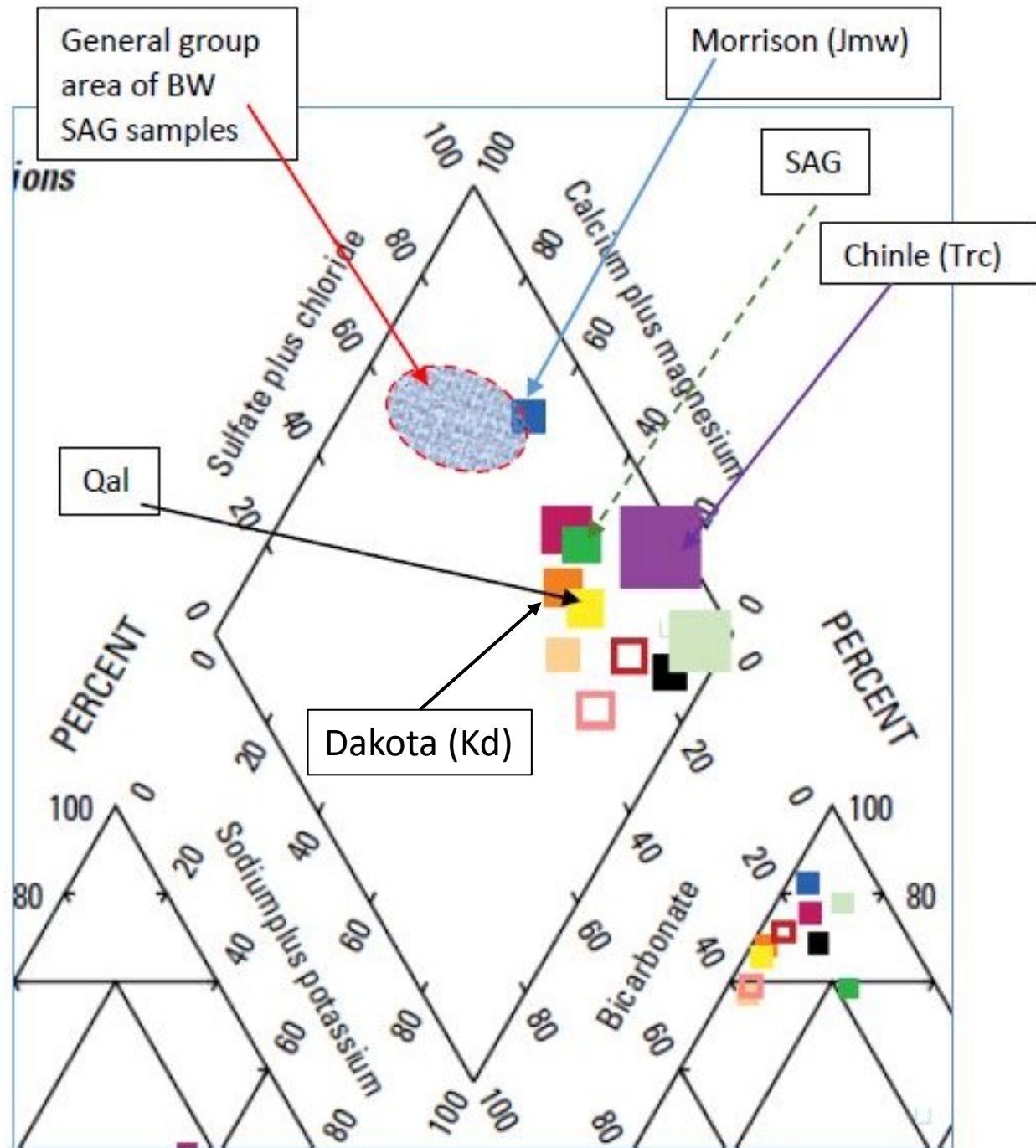
- ASSESS WATER TYPES OF THREE MAJOR HYDROSTRATIGRAPHIC UNITS
 - Alluvium
 - Alluvium – Bedrock Mix
 - Bedrock
- IDENTIFIED BASED ON GEOCHEMISTRY

USGS TRILINEAR (PIPER) DIAGRAM

Upper San Mateo Creek
Basin Study

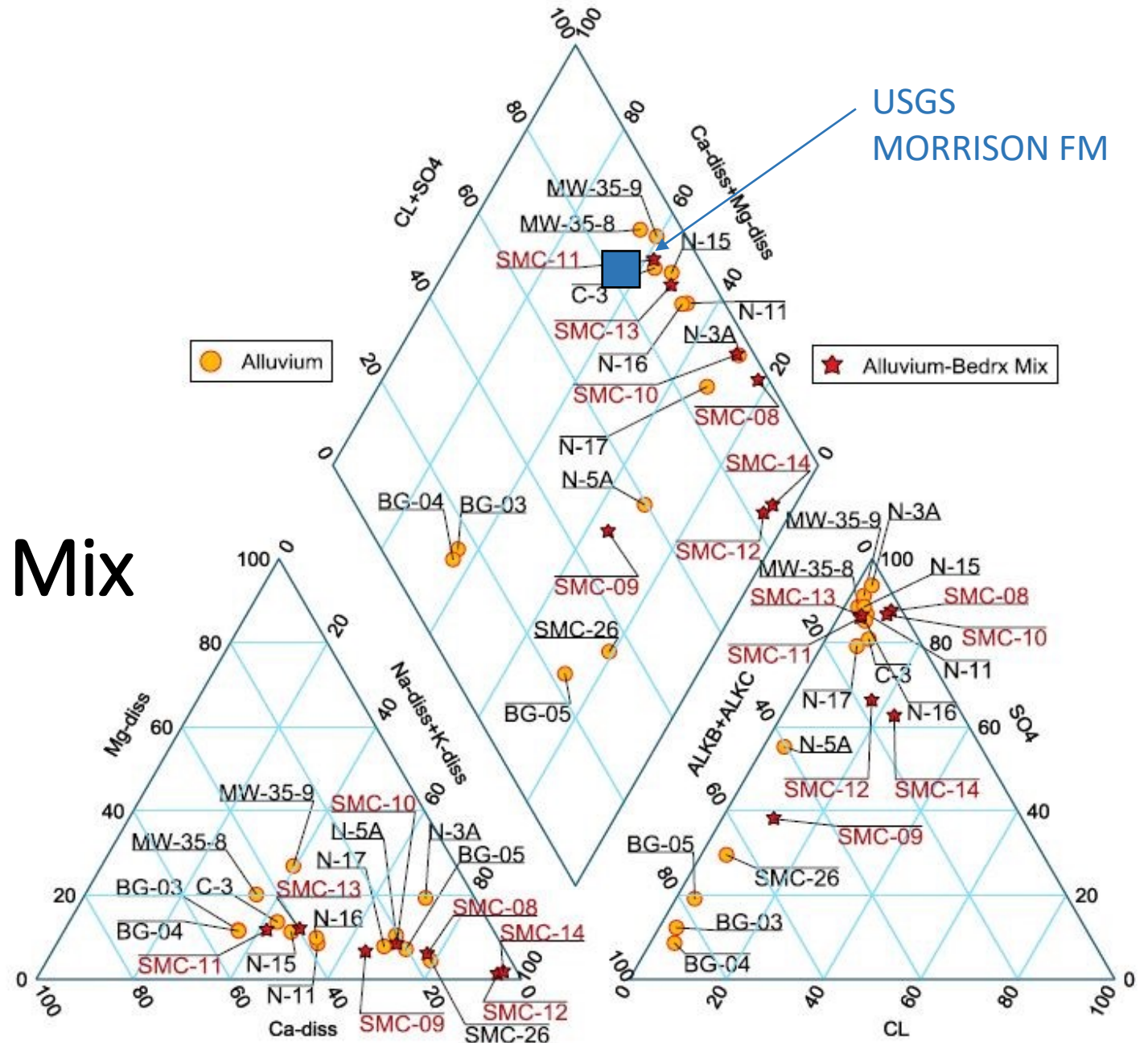
*Assessment of
Ion Composition*

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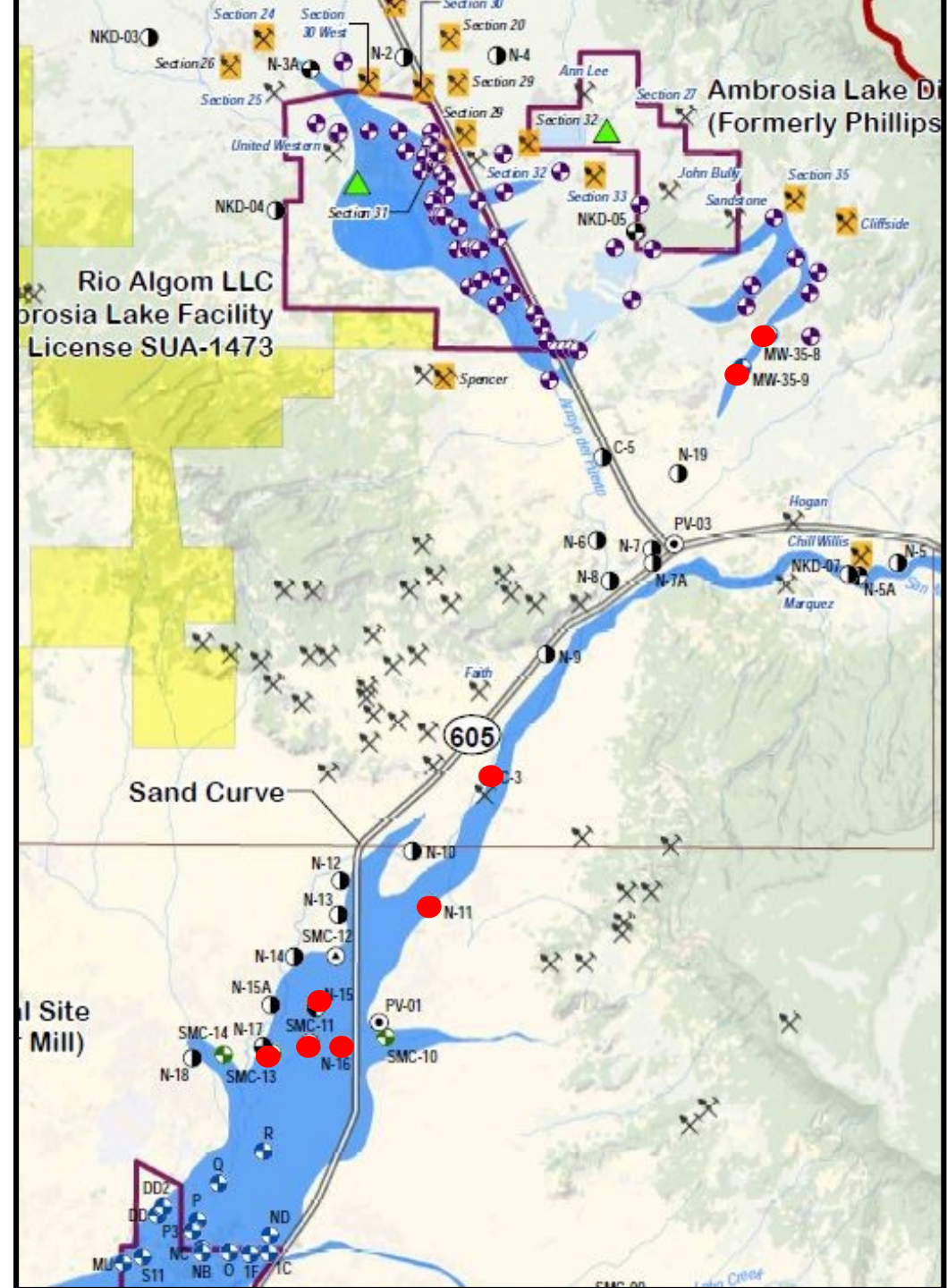


PHASE 2 TRILINEAR (PIPER) DIAGRAM

Alluvium
and
Alluvium – Bedrock Mix



ALLUVIAL WATER WITH MORRISON FM MAJOR ION COMPOSITION



Draft – For Discussion Purposes Only

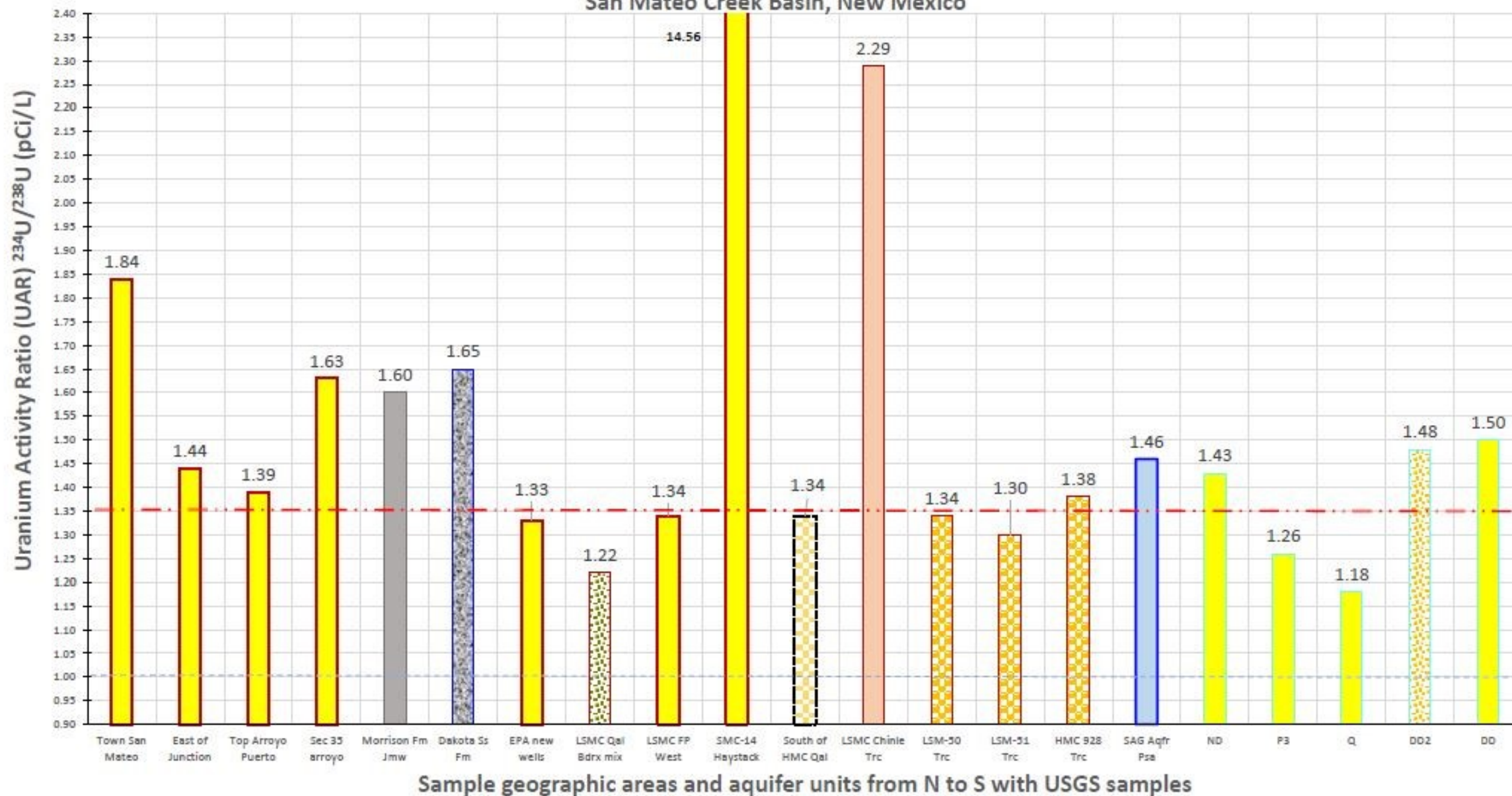
Bedrock



URANIUM ACTIVITY RATIO (UAR)

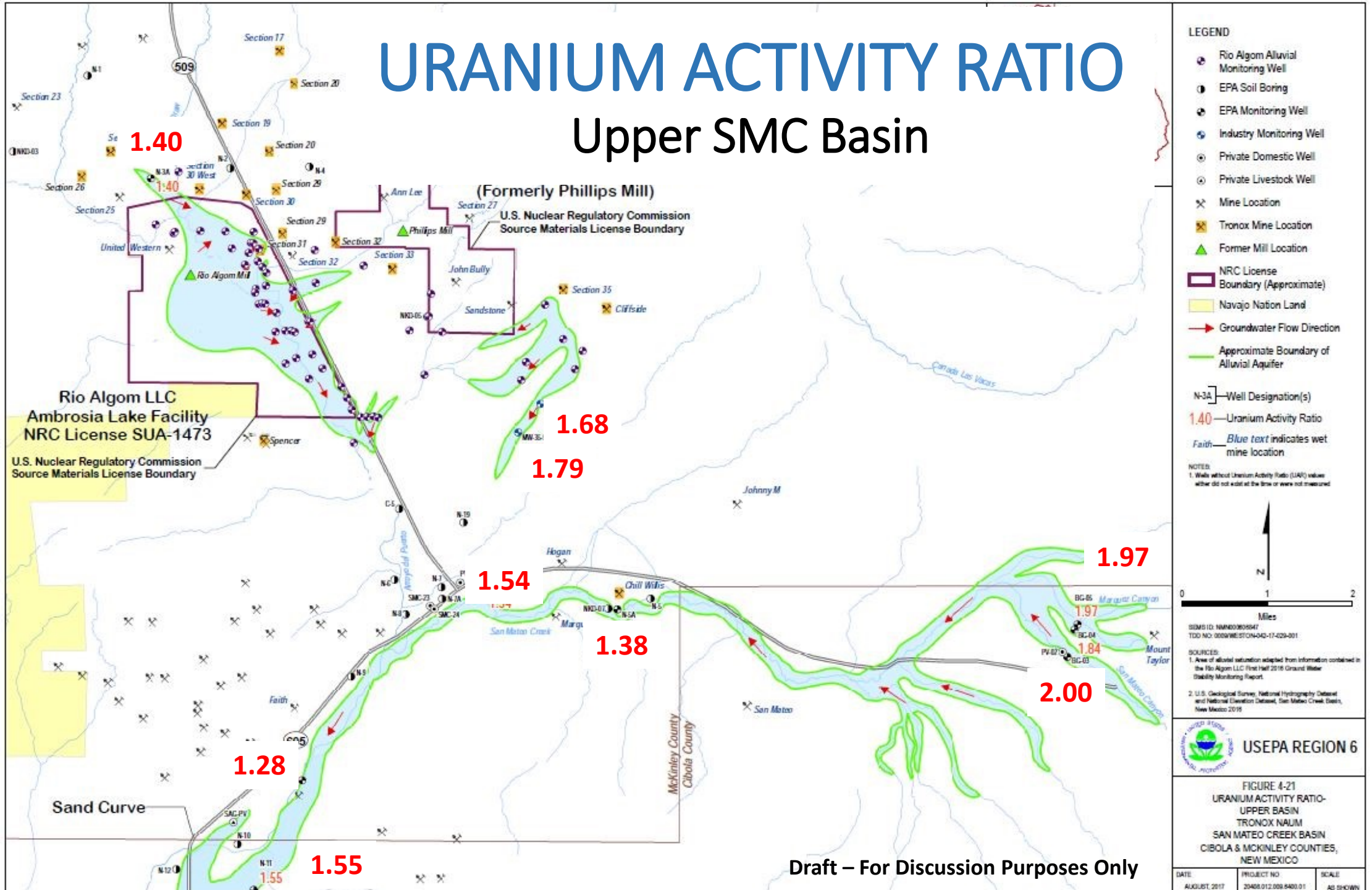
- U-234/U-238 RATIO
- DISTINGUISH BETWEEN MILL/MINE URANIUM CONTAMINATION AND NATURALLY OCCURRING BACKGROUND
 - U-234 AND U-238 Reach Secular Equilibrium in Closed System (Rock)
 - U-234 Production from U-238 Decay = U-234 Loss through Decay
 - $UAR = 1.0$
 - U-234 Preferentially Released in Ground Water
 - Caused by Disruption of crystalline structure
 - Elevates UAR Values in most natural ground waters
- $UAR \text{ VALUES} > 1.5 = \text{BACKGROUND}$
- $UAR \text{ VALUES} < 1.35 = \text{URANIUM MINE OR MILL SOURCE}$

Uranium Activity Ratio (UAR) for sample geographic areas and aquifer units, P2/USGS groundwater samples, San Mateo Creek Basin, New Mexico



URANIUM ACTIVITY RATIO

Upper SMC Basin



1.40

1.68

1.79

1.54

1.38

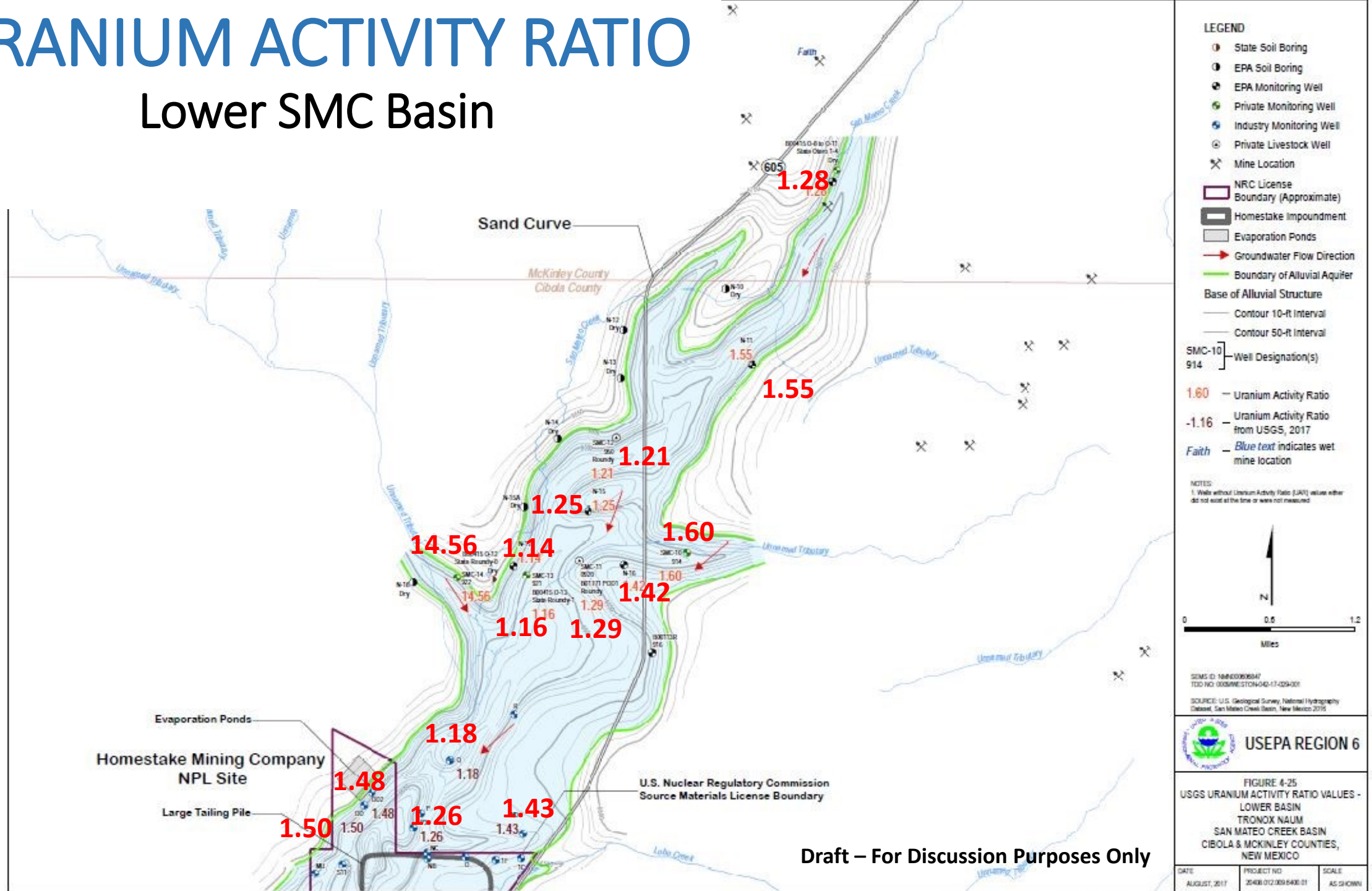
1.97

2.00

1.28

1.55

Lower SMC Basin



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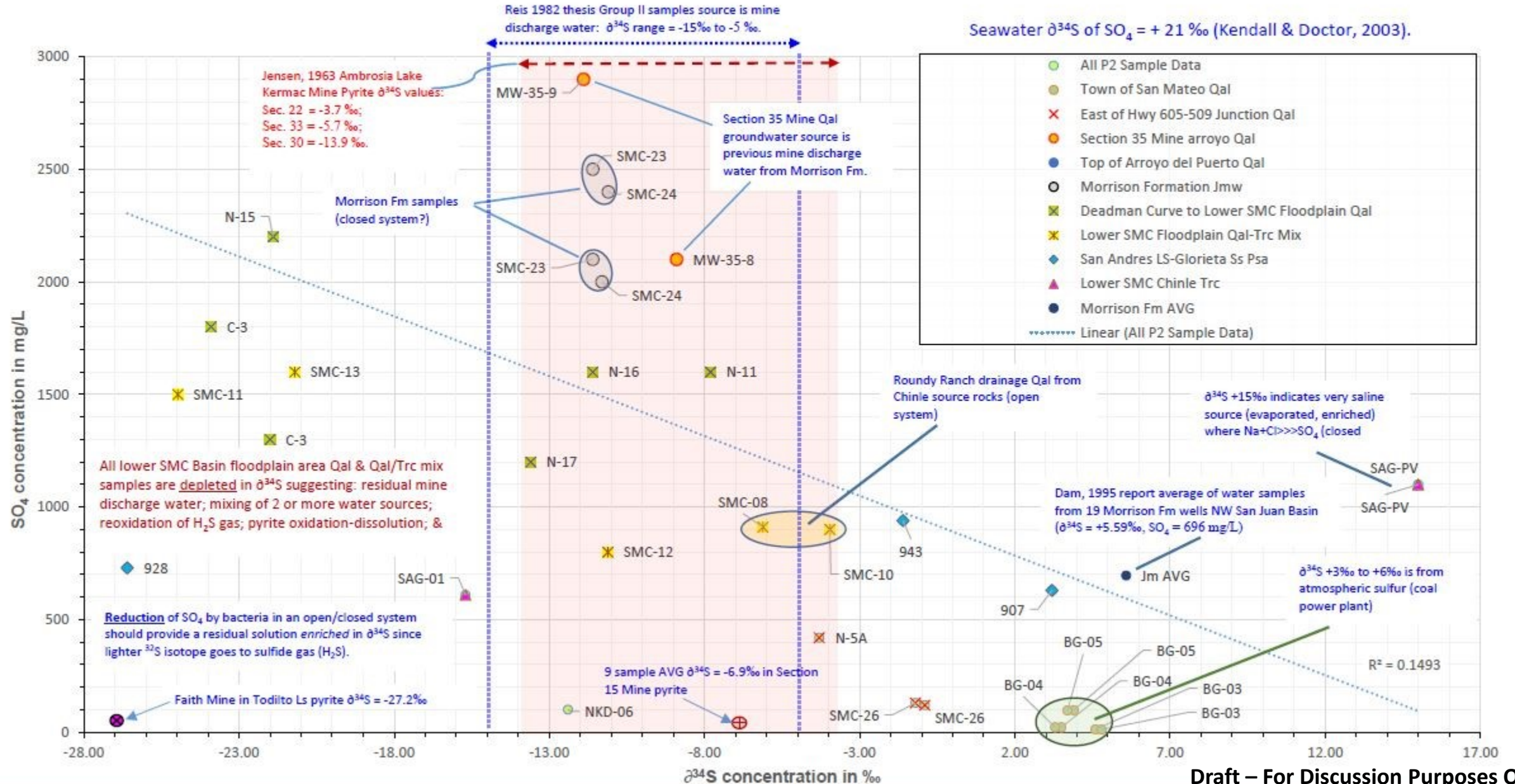
$\delta^{34}\text{S}$ ISOTOPE

- ISOTOPIC COMPOSITION OF SULFUR ($\delta^{34}\text{S}$) IS KNOWN
 - For Global, Regional and Local Sources
 - Sulfate Minerals (Gypsum, Anhydrite)
 - Sedimentary Sulfides (Pyrite)
 - ✓ Sandstone-Type Uranium Deposits in Colorado and Grants Area
- USED AS TRACER OR FINGERPRINT TO SOURCE OF SULFATE



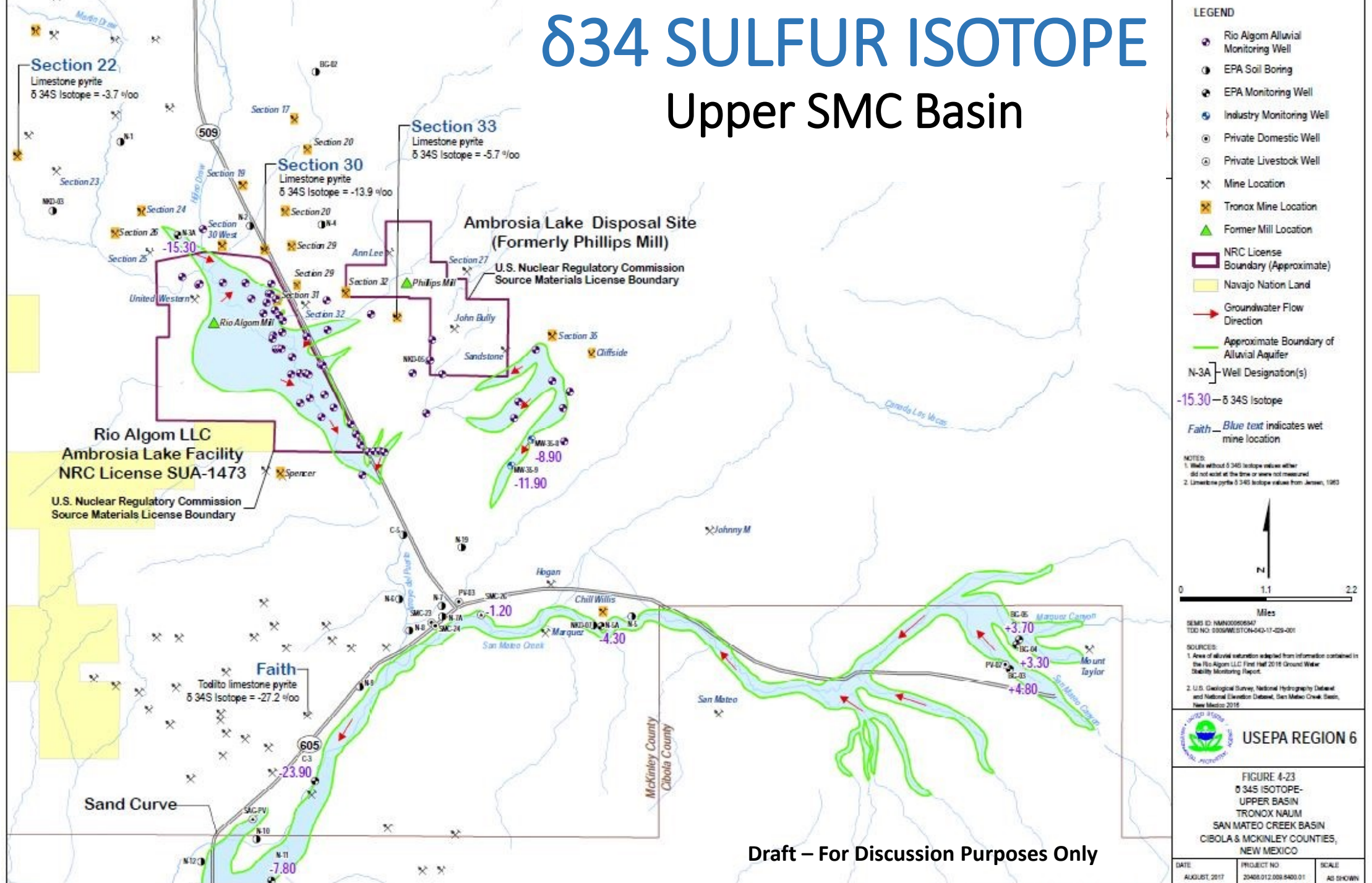
SULFUR ISOTOPE ASSESSMENT

$\delta^{34}\text{S}$ concentration in ‰ versus SO_4 concentration in mg/L, P2 groundwater samples, San Mateo Creek Basin, New Mexico

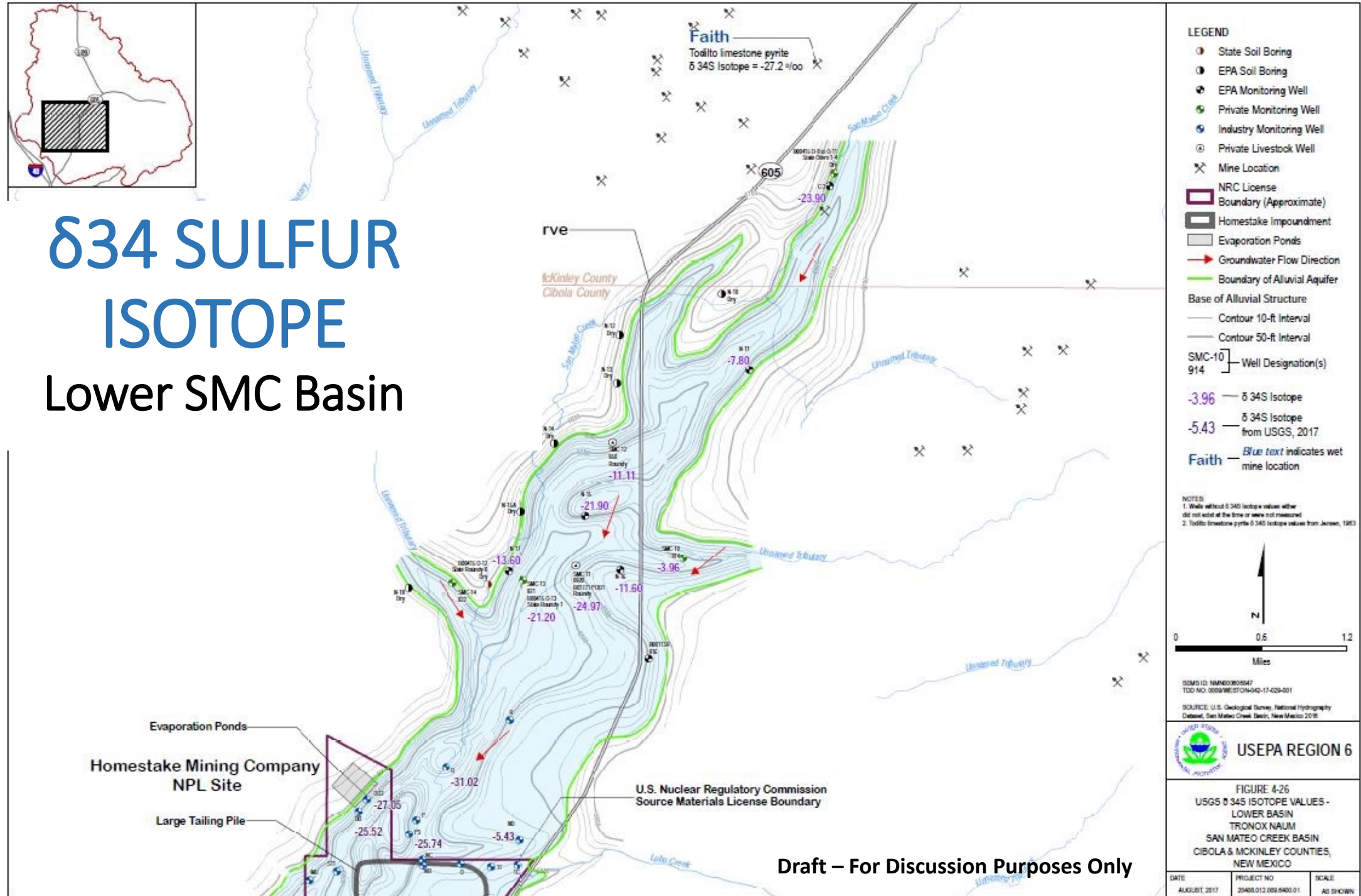


$\delta^{34}\text{S}$ SULFUR ISOTOPE

Upper SMC Basin



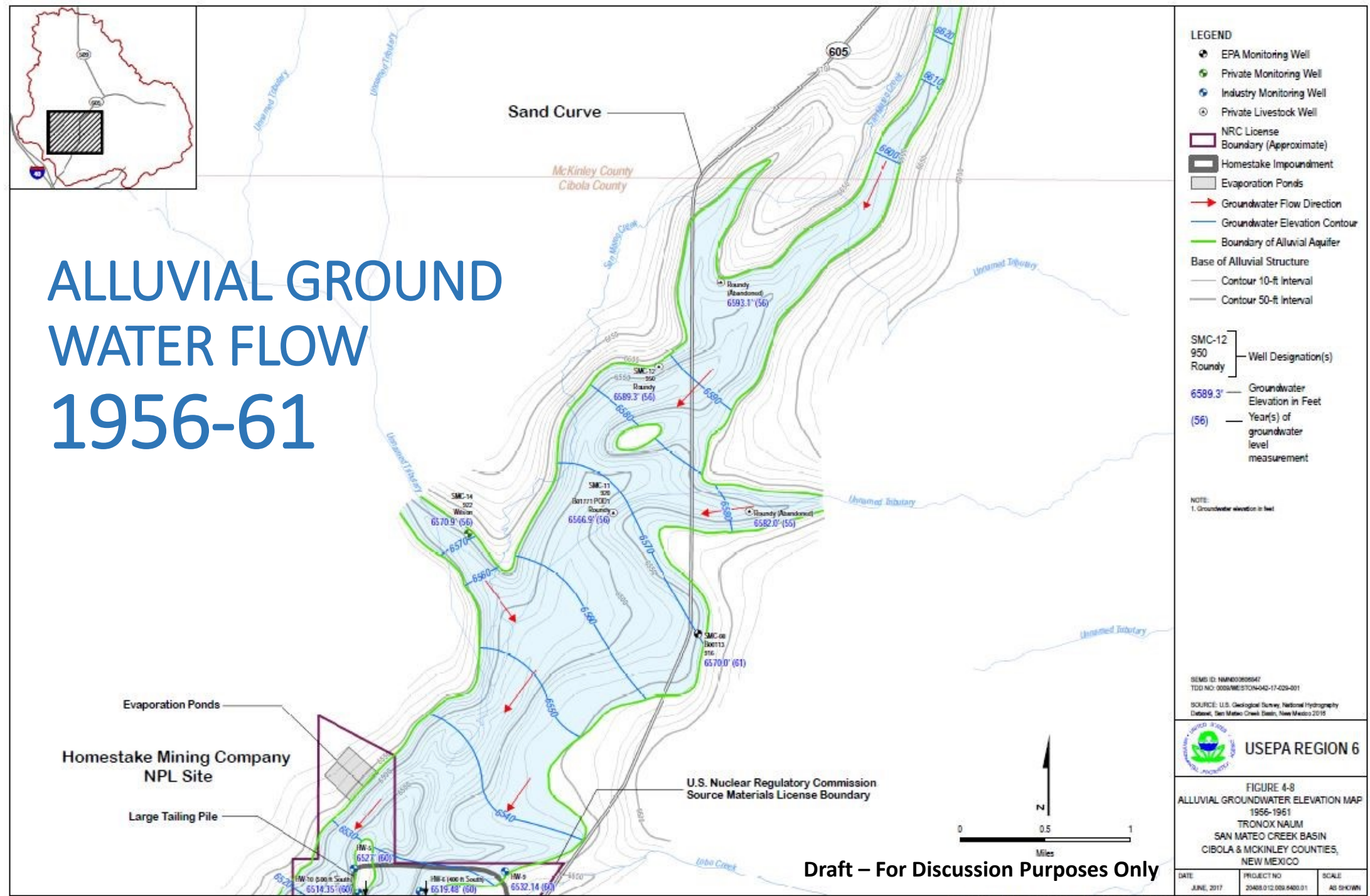
$\delta^{34}\text{S}$ SULFUR ISOTOPE Lower SMC Basin



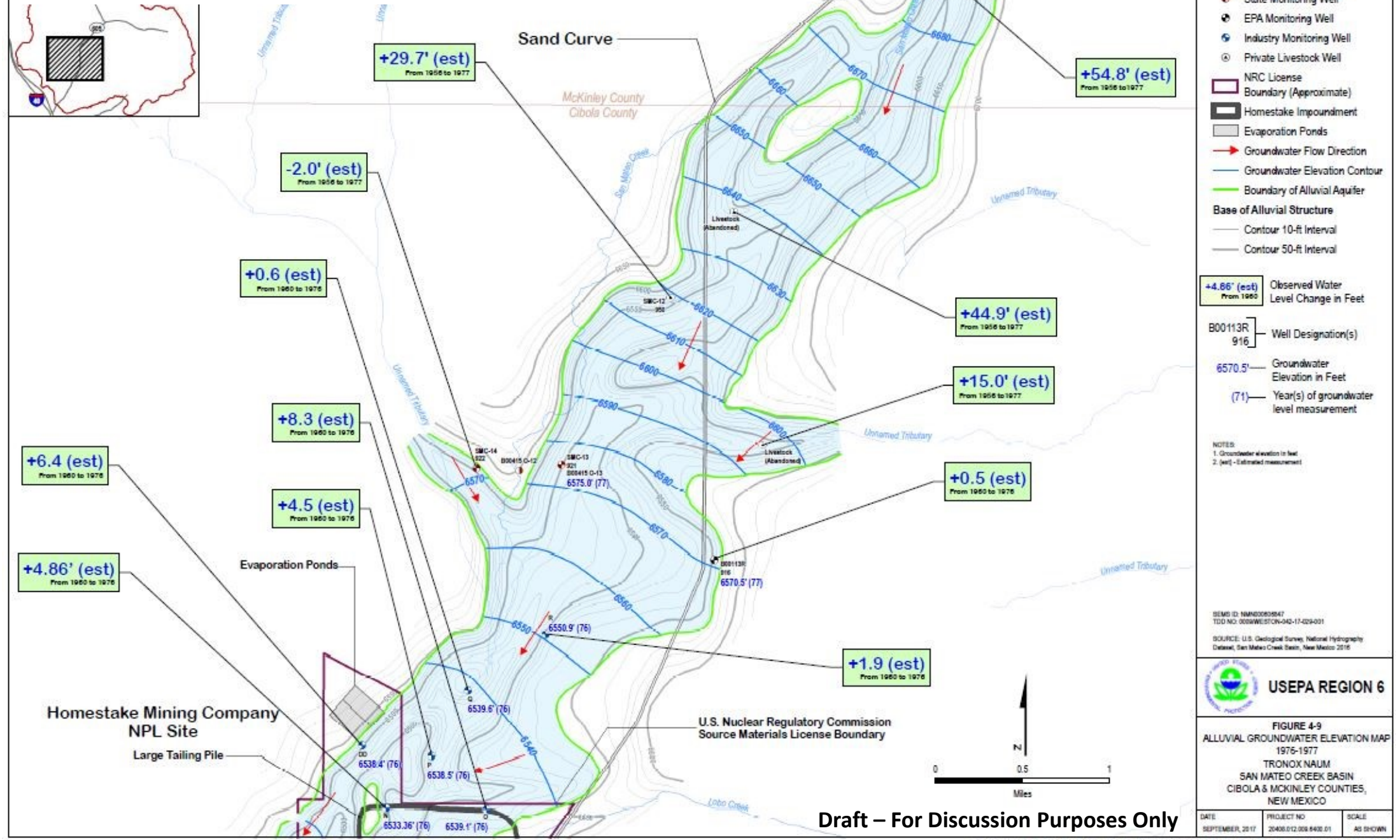
LEGACY MINE DISCHARGE WATER IMPACTS

- MAP CHANGES IN WATER LEVELS OVER TIME
 - Identify Physical Presence of Mine Discharge Water
- MAP CHANGES IN WATER QUALITY OVER TIME
 - Plume Maps for Key Constituents
- TEMPORAL PLOTS OF CONSTITUENT CONCENTRATIONS
 - Look for Upward Trends

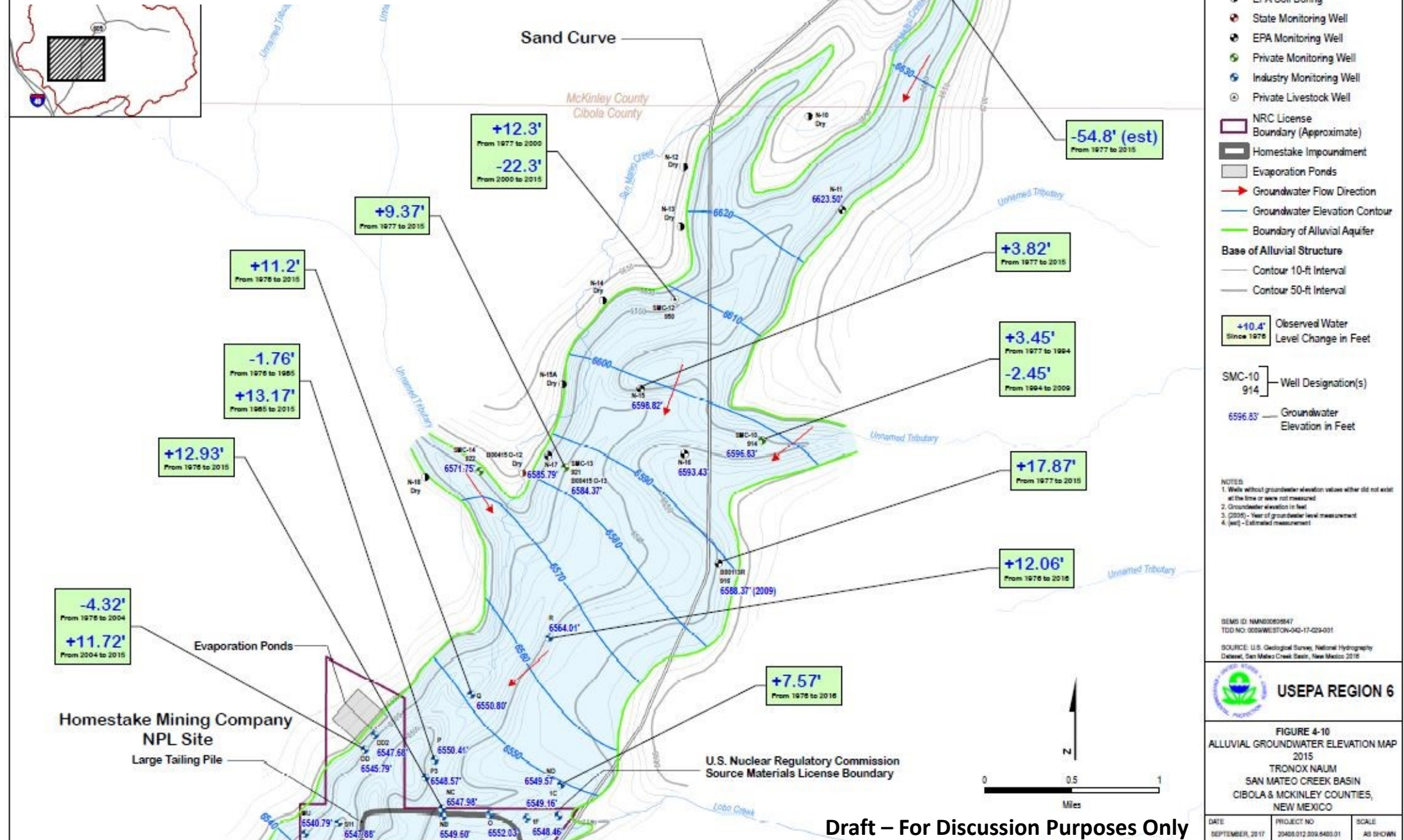
ALLUVIAL GROUND WATER FLOW 1956-61



ALLUVIAL GROUND WATER FLOW 1977



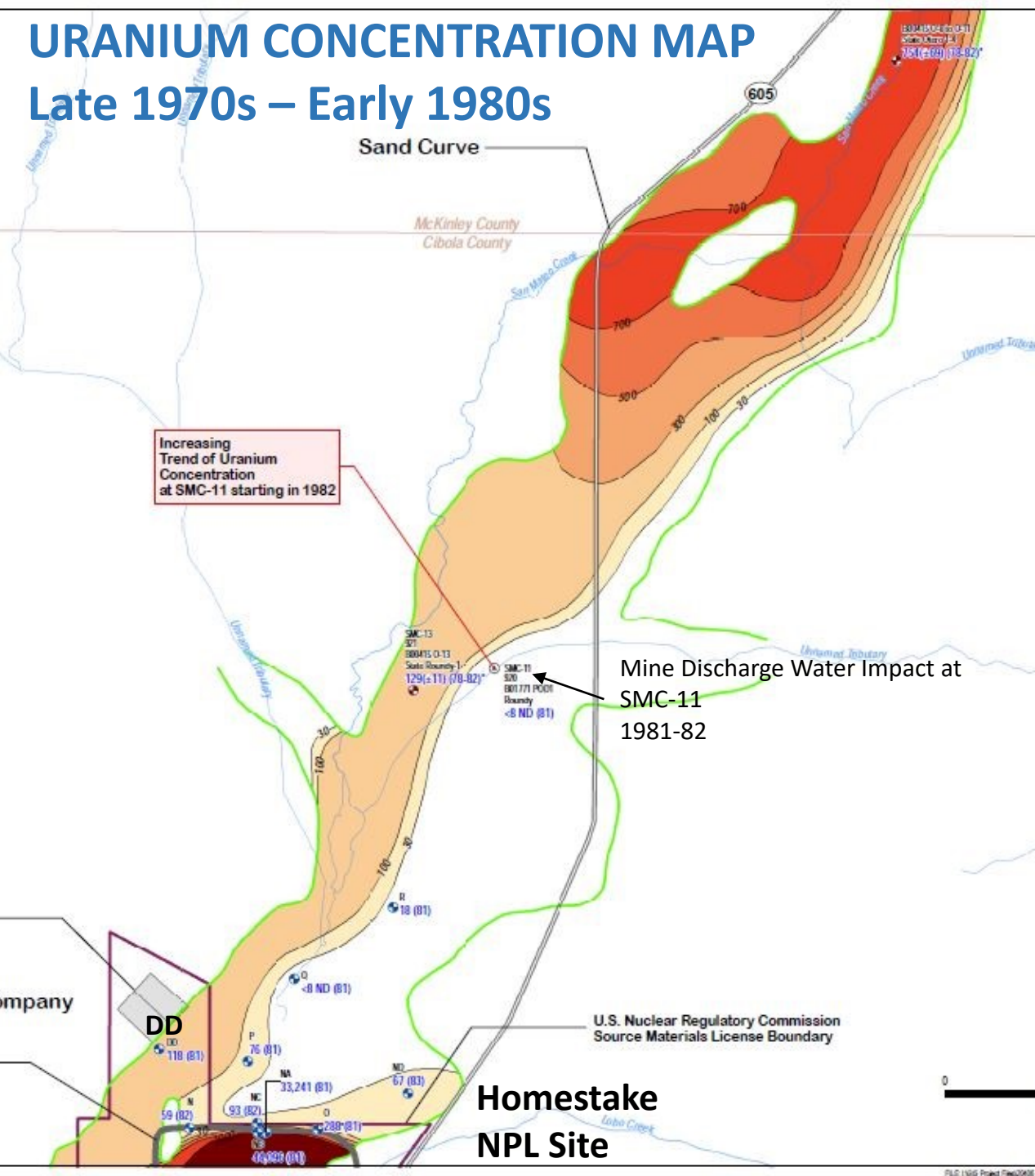
ALLUVIAL GROUND WATER FLOW 2015



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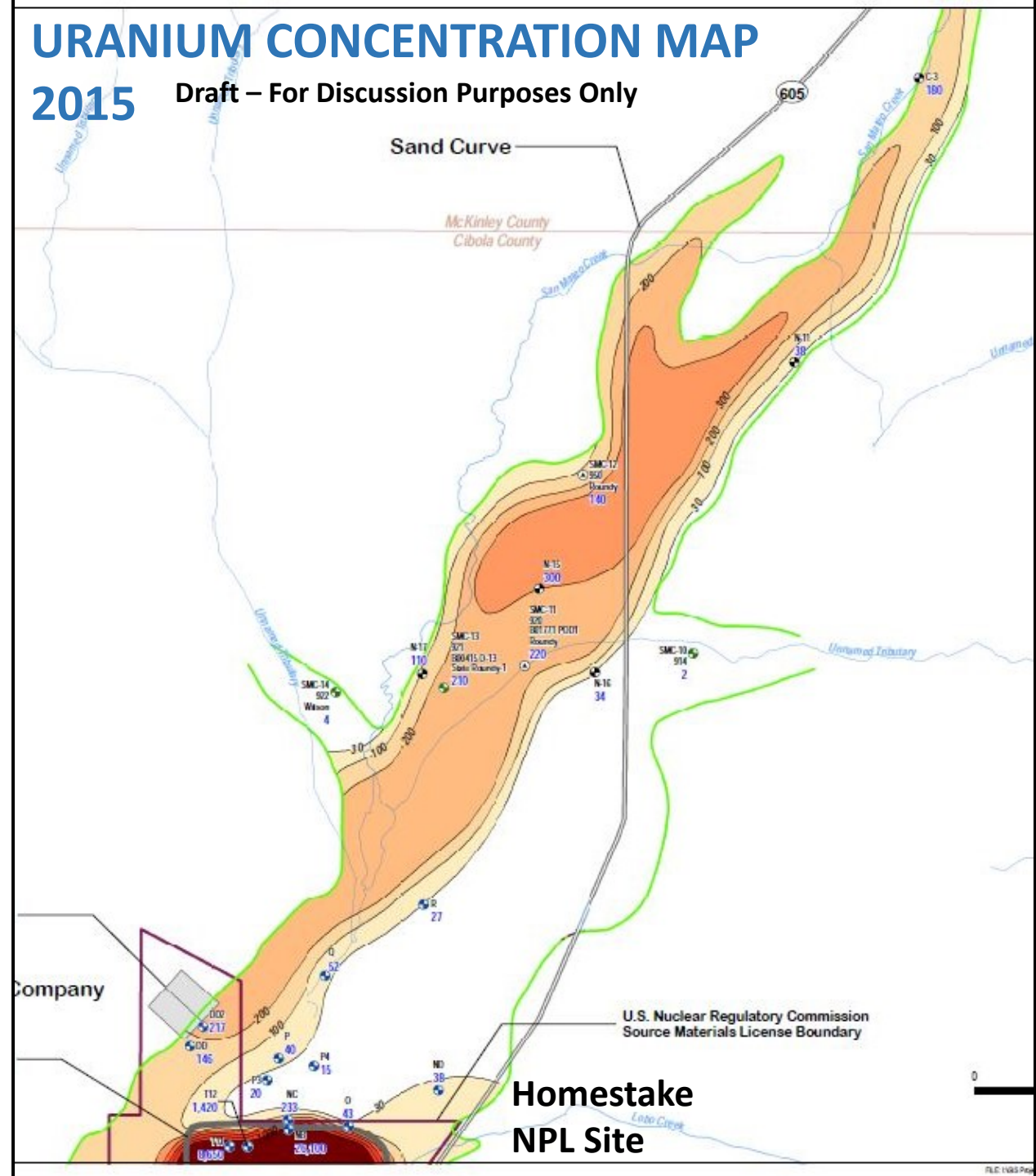
URANIUM CONCENTRATION MAP

Late 1970s – Early 1980s

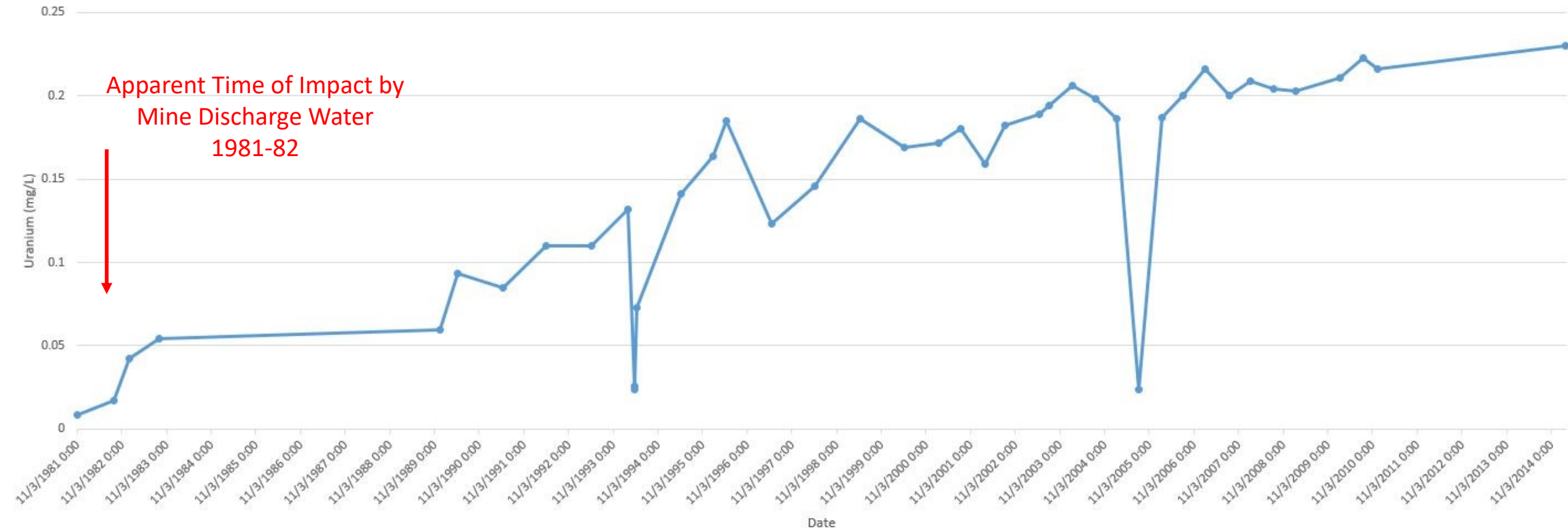


URANIUM CONCENTRATION MAP

2015 Draft – For Discussion Purposes Only

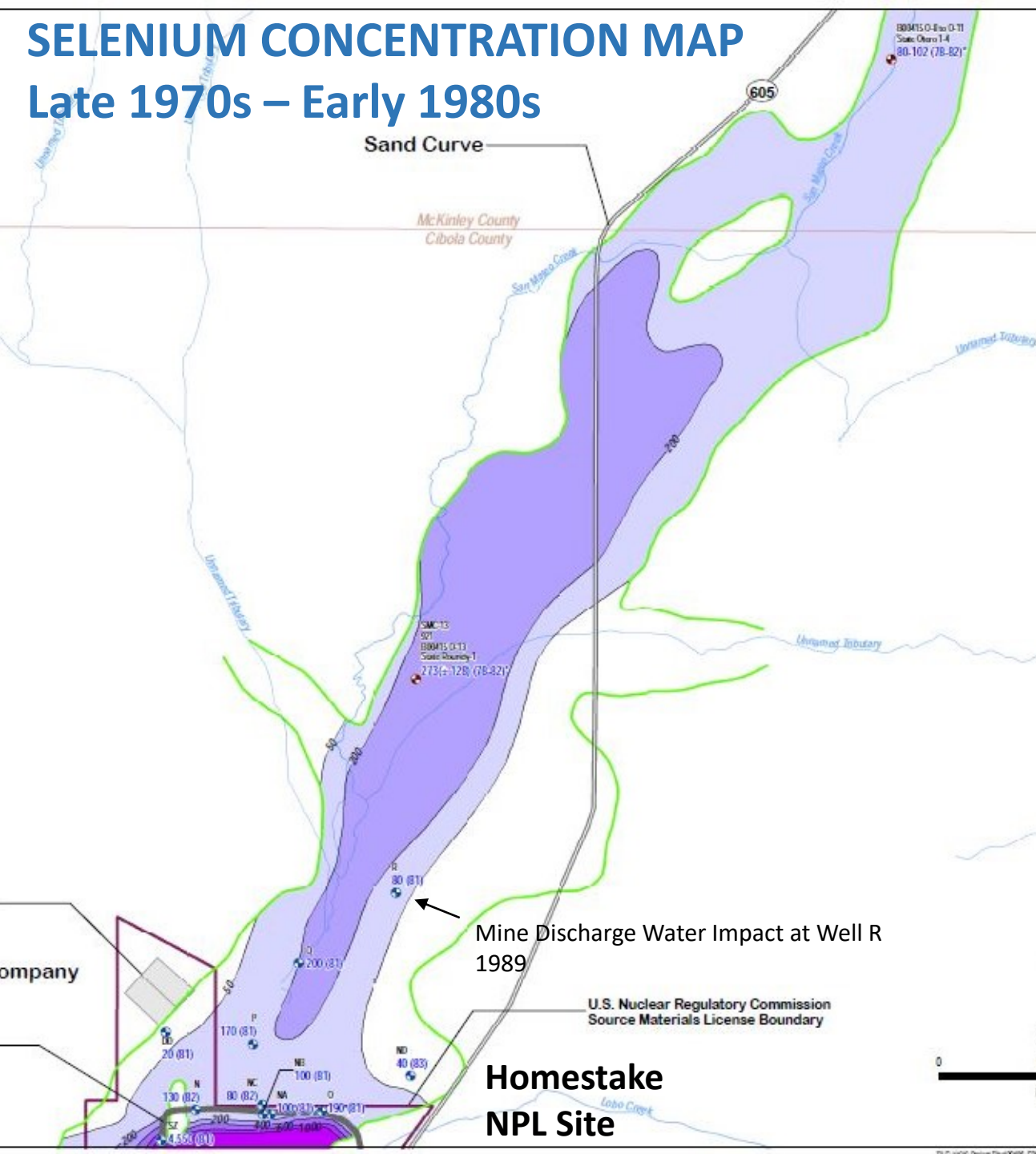


Homestake Well 920 (SMC-11) Uranium-Time Trend Plot



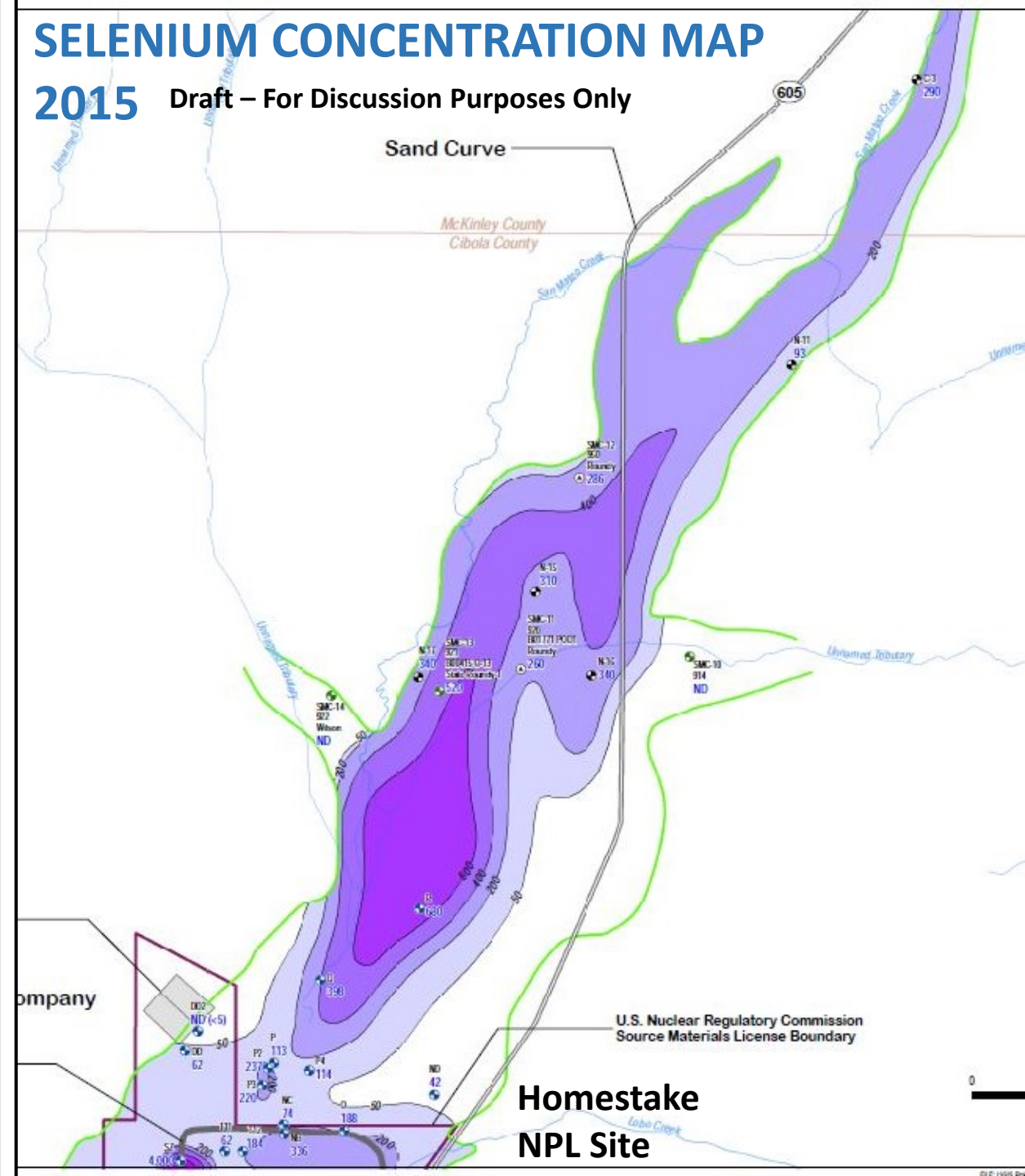
SELENIUM CONCENTRATION MAP

Late 1970s – Early 1980s

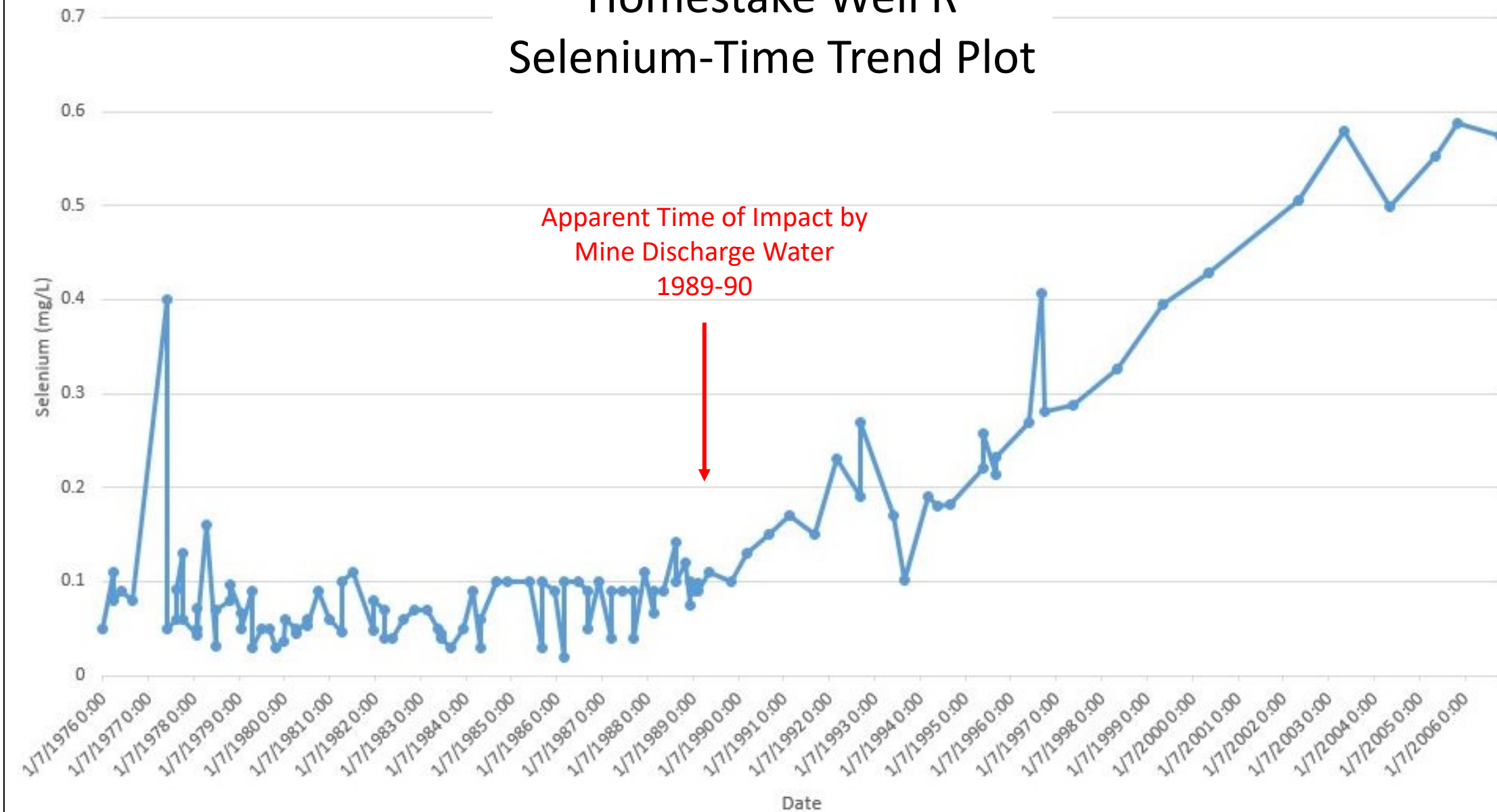


SELENIUM CONCENTRATION MAP

2015 Draft – For Discussion Purposes Only

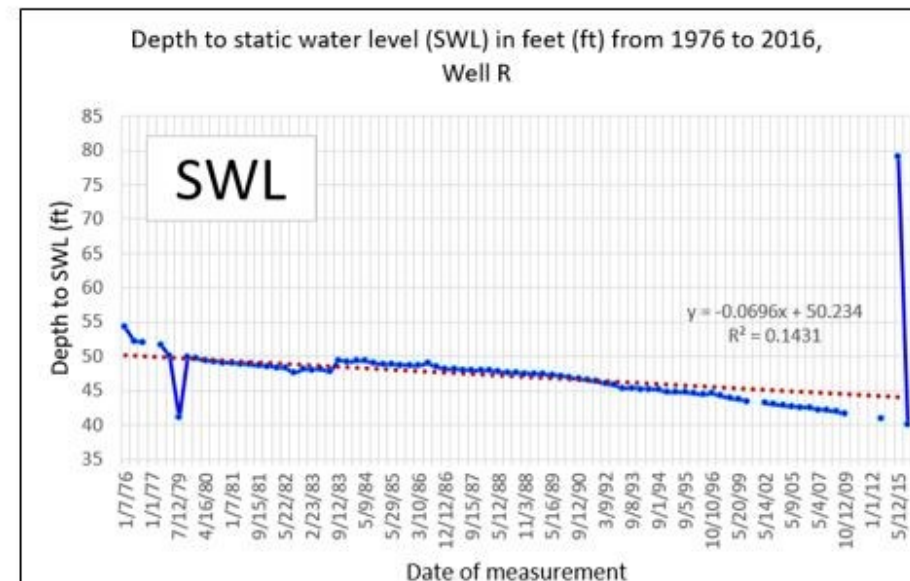
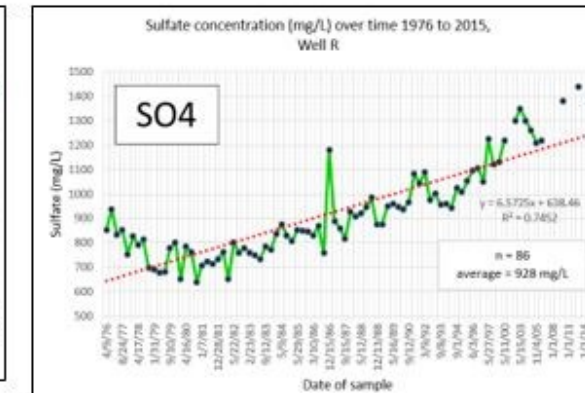
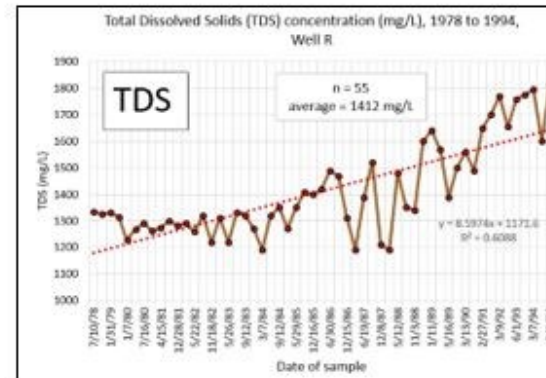
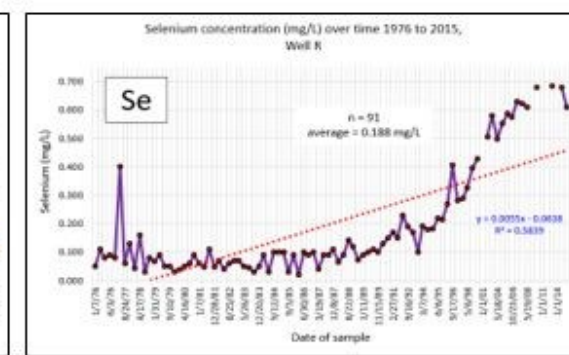
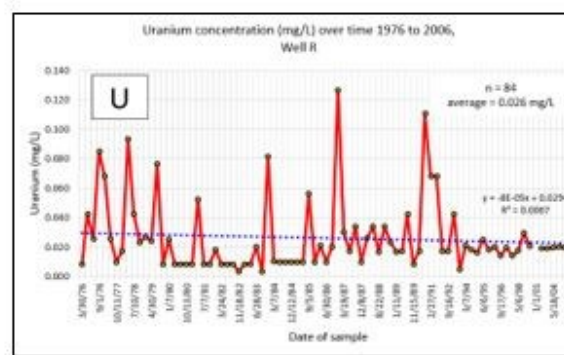


Homestake Well R Selenium-Time Trend Plot



WELL R

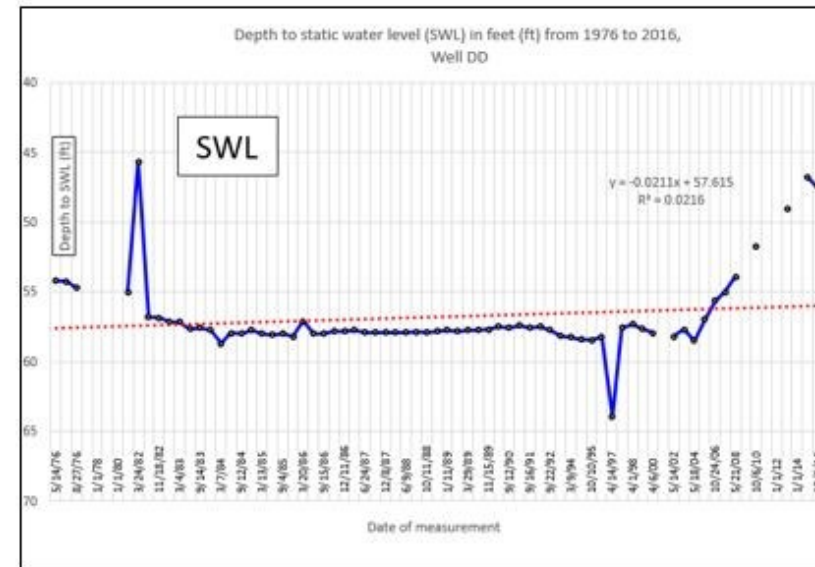
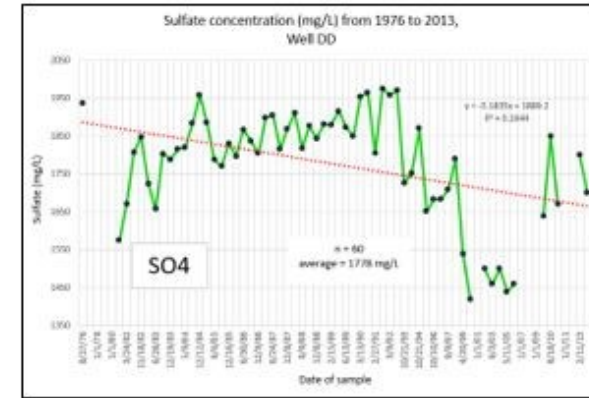
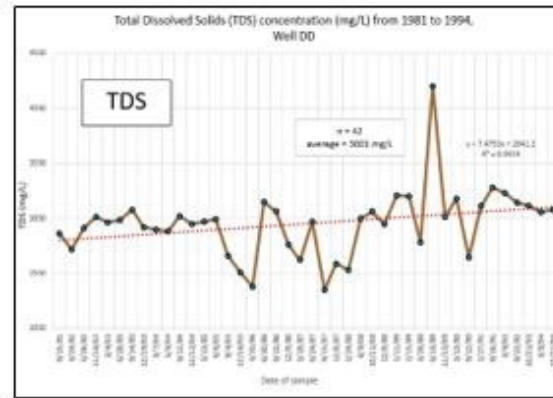
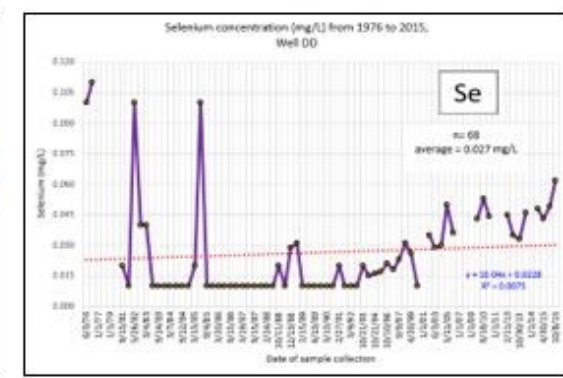
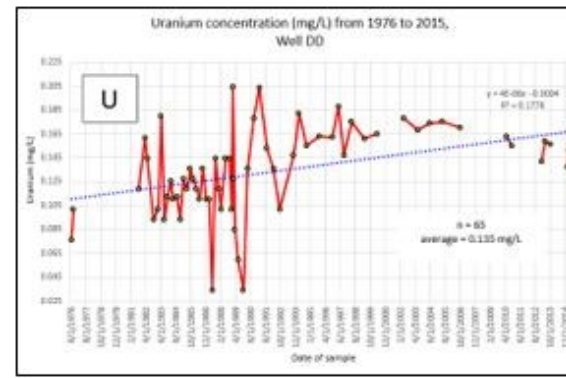
TEMPORAL PLOTS OF CONSTITUENTS CONCENTRATIONS



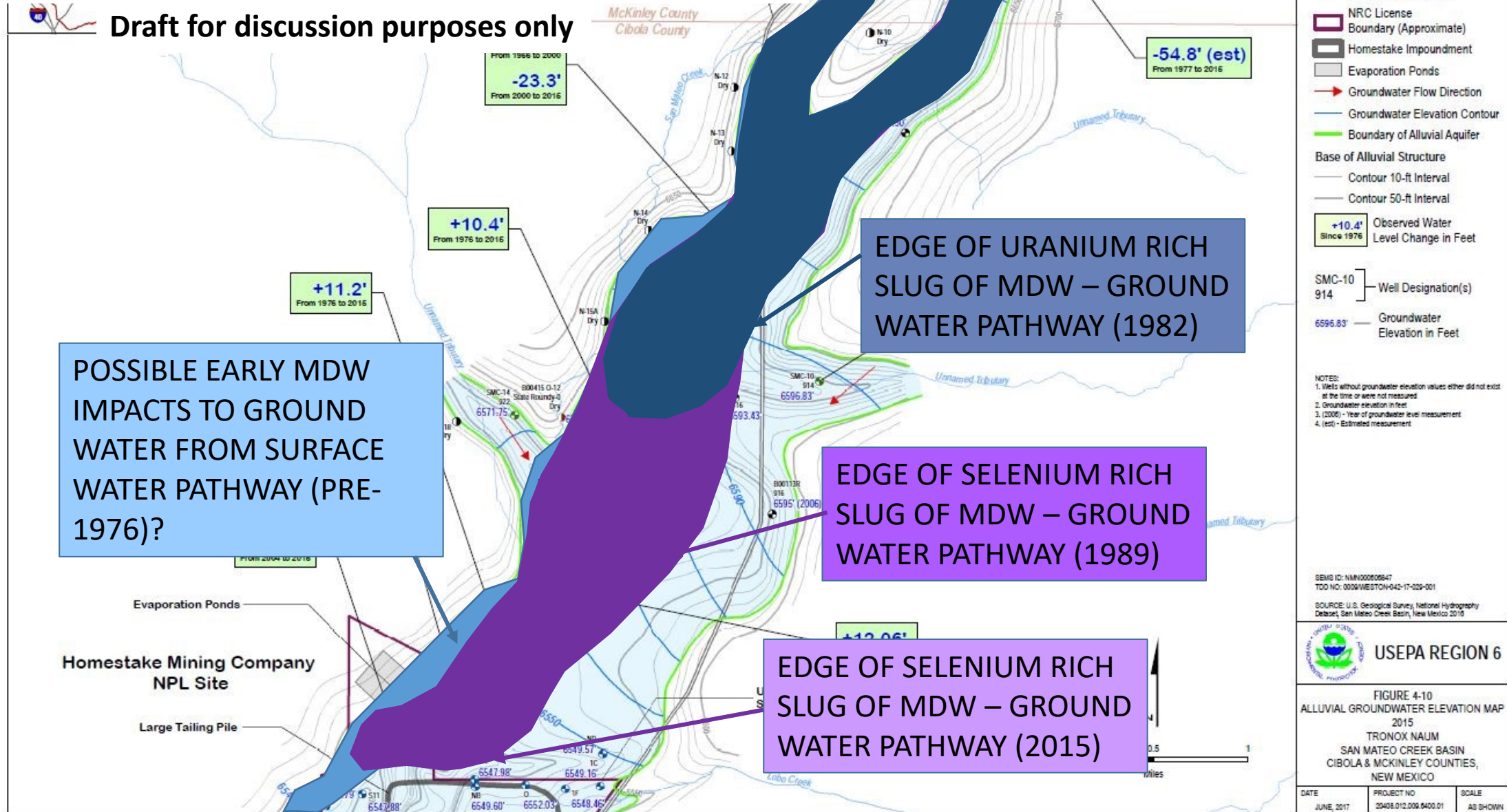
WELL DD

TEMPORAL PLOTS OF CONSTITUENT CONCENTRATIONS

HISTORICALLY HIGH
URANIUM
(Since Monitoring
Began in 1976)



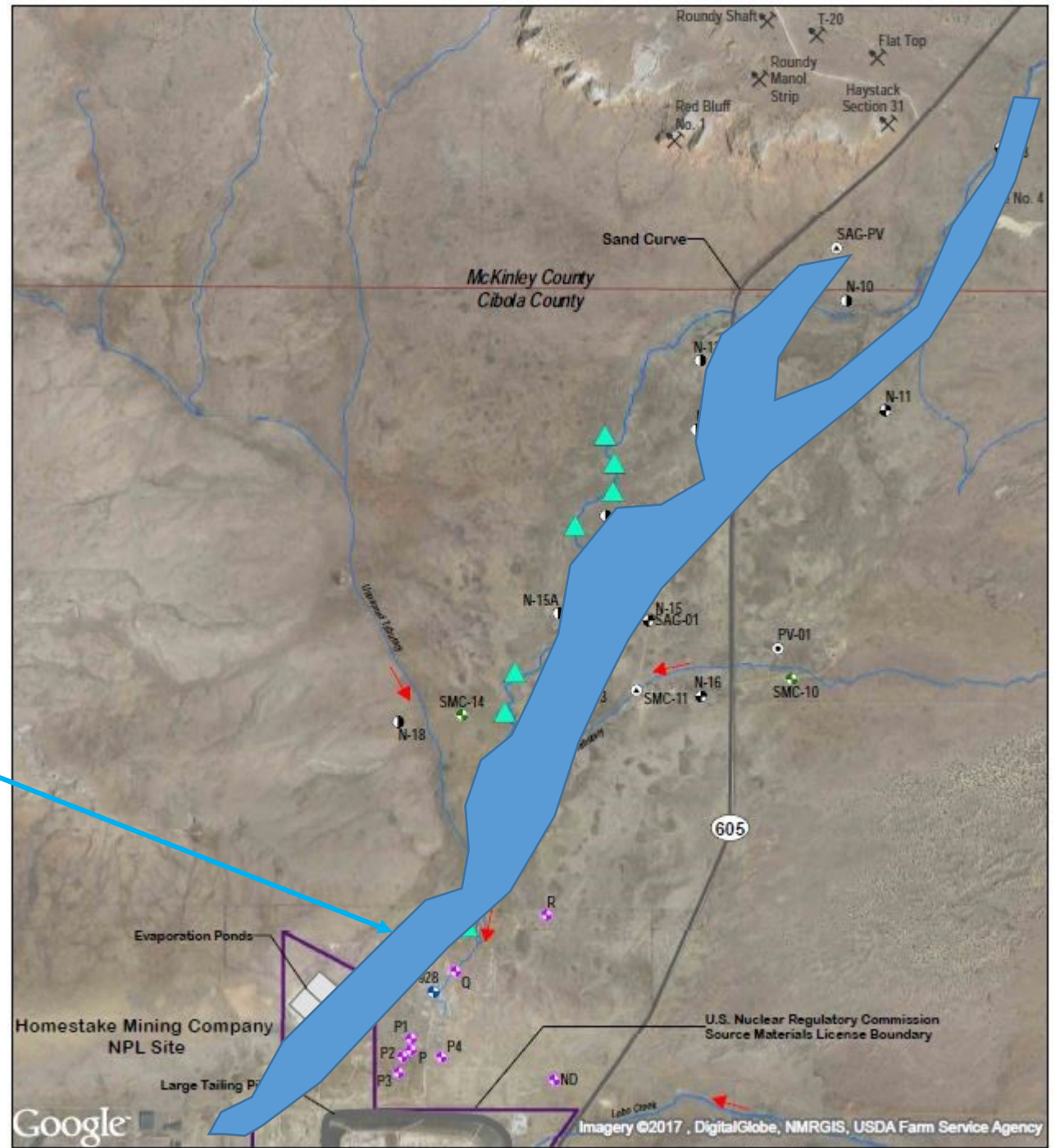
CONCEPTUALIZED IMPACTS OF MINE DISCHARGE WATER



POSSIBLE SURFACE WATER FLOW PATH FOR EARLY URANIUM

▲ SPREADER DAMS
FOR CATTLE FORAGE

POSSIBLE EARLY
MINE DISCHARGE WATER
IMPACTS TO GROUND
WATER FROM SURFACE
WATER PATHWAY (PRE-
1976)?

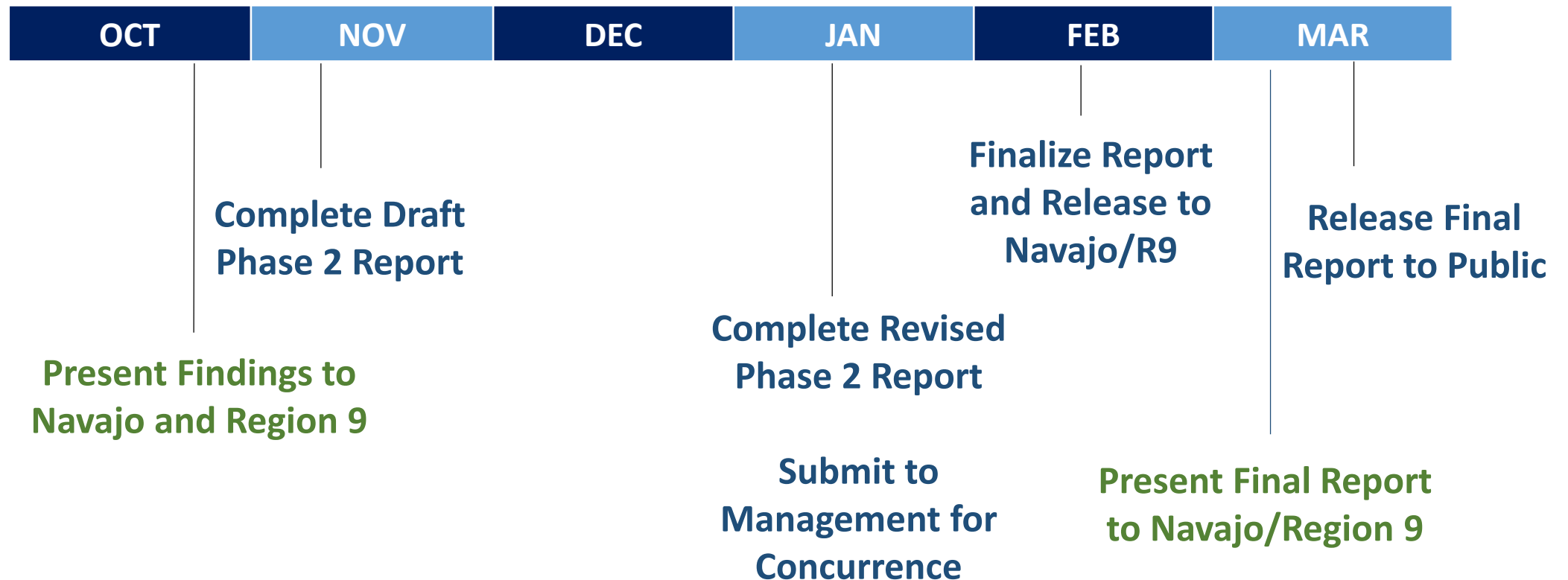


DRAFT PHASE 2 REPORT NEAR COMPLETION

- DISCUSSION AND CONCLUSION SECTIONS YET TO BE WRITTEN
- MUST LOOK AT MULTIPLE LINES OF EVIDENCE TO SUPPORT FINDINGS AND CONCLUSIONS
 - Individual Lines of Evidence May Not be Conclusive

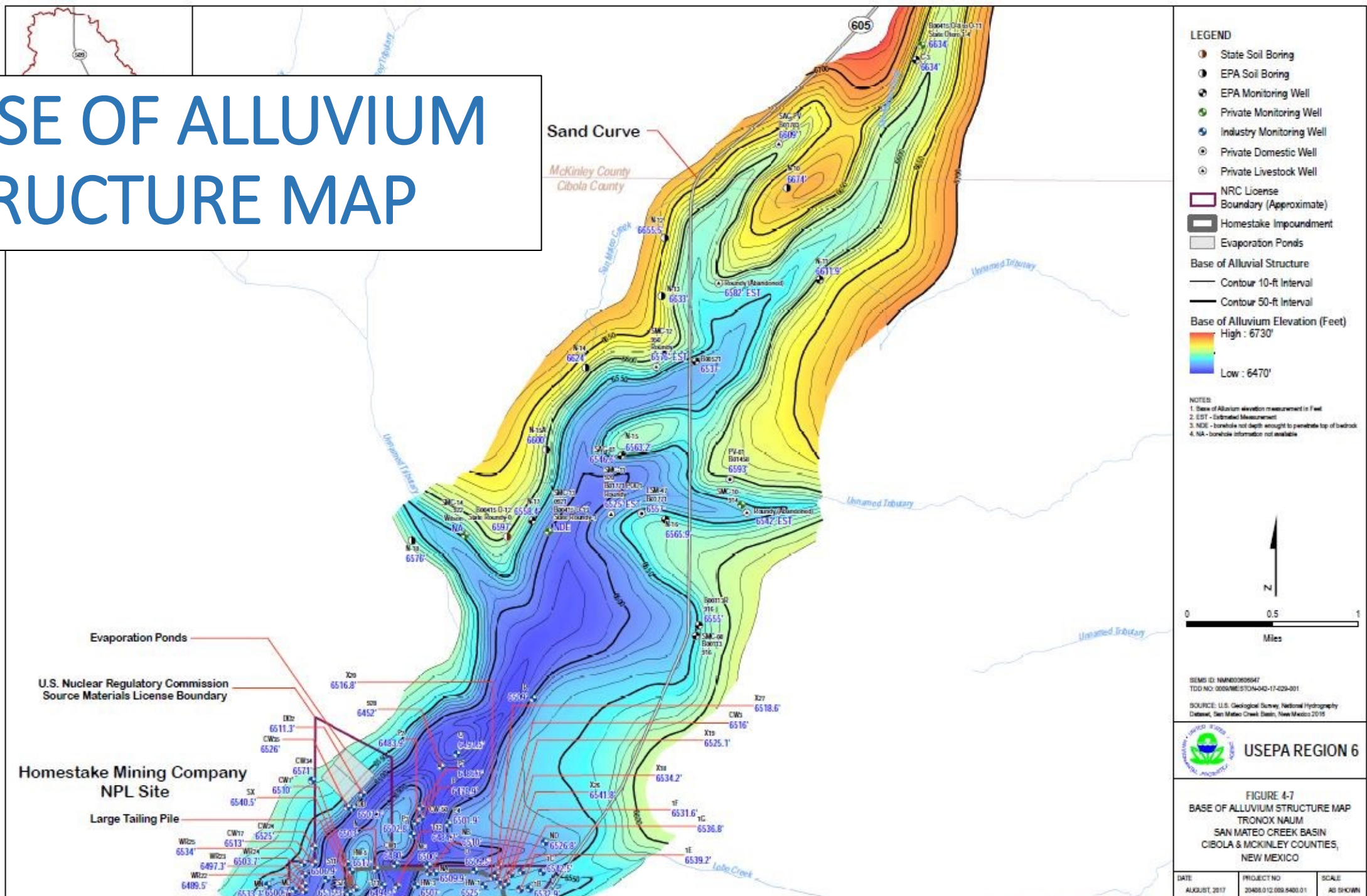


REPORT COMPLETION SCHEDULE – 2017/2018

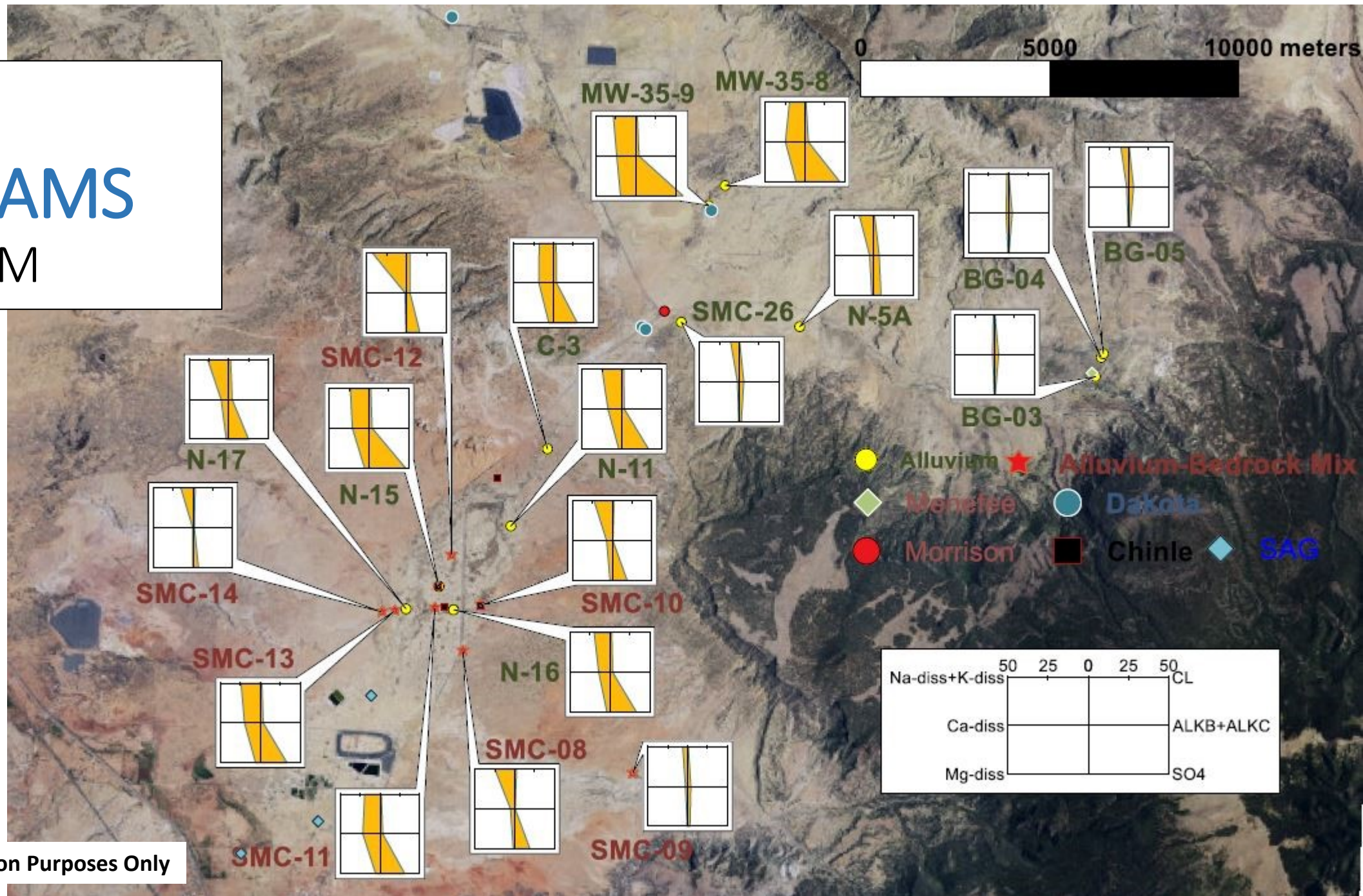


OTHER SLIDES

BASE OF ALLUVIUM STRUCTURE MAP

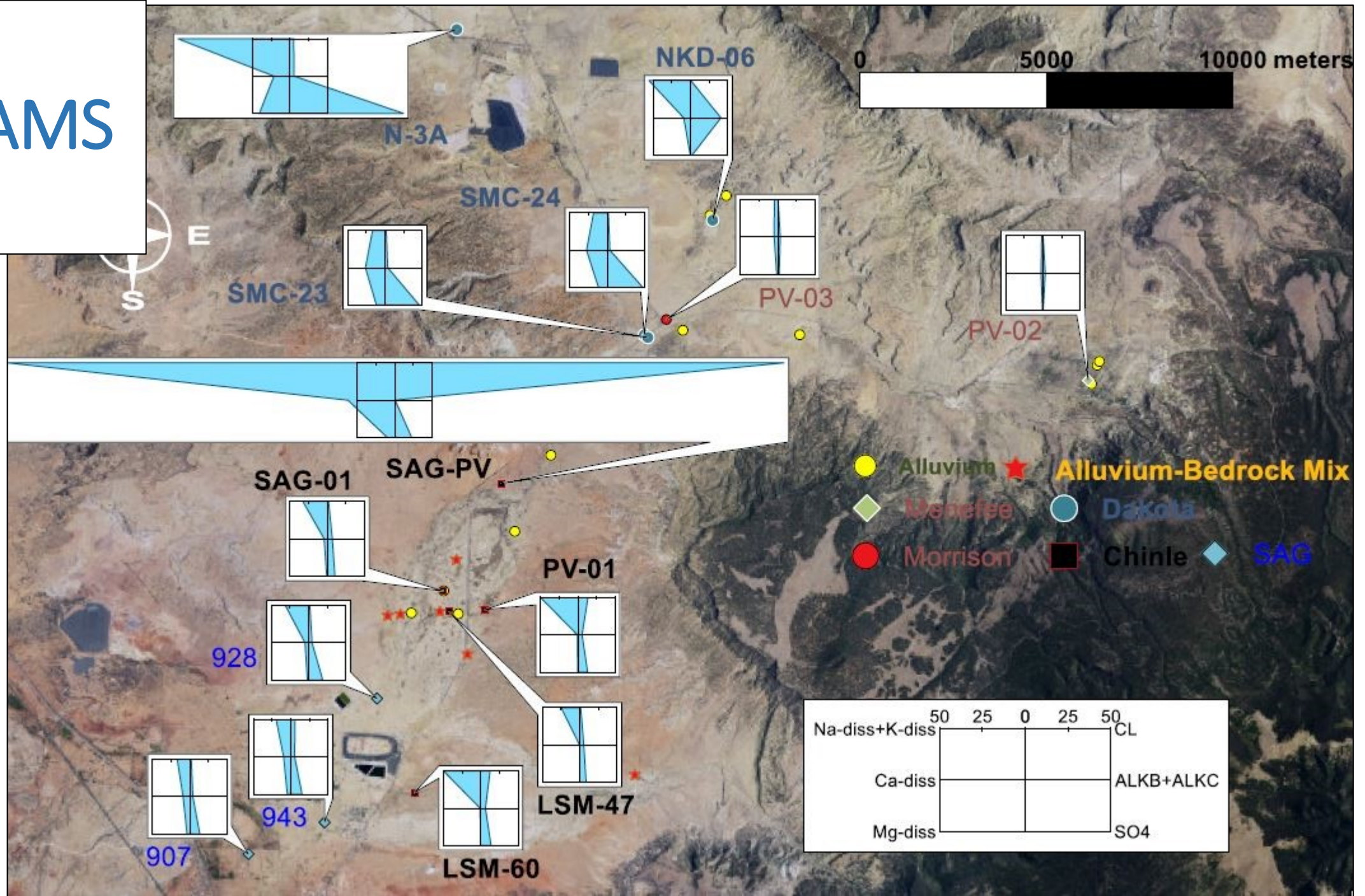


STIFF DIAGRAMS ALLUVIUM



Draft – For Discussion Purposes Only

STIFF DIAGRAMS BEDROCK



Bluewater Mill Site and Homestake NPL Site Milan Area

- Alluvium
- Upper Chinle SS
- Middle Chinle SS
- Lower Chinle
- San Andres/
Glorietta (SAG)

